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RADIOLOGY

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NEW APPLICATION OF FLAT BUCKY GRID TO ANY ANGLE WITH SPECIAL REFERENCE TO SINUS WORK[1]

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ONE has to examine the dried skull only casually to note the roentgenologic difficulties in its examination with special reference to the paranasal sinuses. We all agree that roentgenograms of the paranasal sinuses must be of excellent quality in contrast, detail, and definition. Just how these results are best obtained is still a debatable question, and, on the whole, roentgenographic examinations of the paranasal sinuses are far from being standardized. A recent text-book (Proetz) on the subject begins, "Discouragingly little is known about sinuses."

The use of the Potter-Bucky diaphragm routinely in head work appears never to have been practical. The reason is clear to all. Just which method of procedure is the best, that is, whether to use the Bucky, or to dispense with it, and use the long narrow cone, does not come within the scope of this paper. The point we wish to make is that, if one so desires, he may use the flat rectangular Bucky grid for any of the many tube tilts and shifts required in the examination of the skull. One other point which we think has been fairly well established in sinus work is that an 8×10 film divided in halves is of sufficient size to show any particular group of sinuses diagnostically. This procedure saves both time and money.

So far as we know, the only solution of adapting the flat Bucky grid to various angles, up to the present time, has been a Bucky so constructed that interchangeable grids especially built for the various angles were used, or the spiral type of grid. For some reason neither of these types has thus far gained wide popularity in America.

Some years ago we made a spiral grid. At that time the idea of an interchangeable grid, which we first learned of through the work of Dr. Potter, did not occur to us. The spiral grid we constructed appeared to be an excellent piece of workmanship, and on trial it made the most beautiful circles on films anyone might wish to see. After discovering our mistake along this line we then conceived the idea of mounting a flat rectangular grid so as to accomplish the results we had hoped to obtain from a spiral grid.

This was accomplished by reassembling the parts of a regulation stock Bucky and having a specially built small grid, 1 to 4 ratio, 0.25 inch thick, installed. This grid and the other mechanical parts of the Bucky were mounted on a rotating aluminum disk, covered with lead to protect the unexposed film. This disk has a diaphragm in the center, 5×8 in., permitting exposure

[1]Read before the Radiological Society of North America, at the Seventeenth Annual Meeting, at St. Louis, Nov. 30–Dec. 4, 1931.

of one-half of the film. The disk is mounted within a metal ring, termed the orbit. In the orbit are ball-bearing rollers that fit into a track on the disk (Fig. 1). The orbit is marked off into degrees, starting with 0 at the top and going to the right and left through the equator of the orbit, giving a total range of 180°. The disk has an indicating hand pointing to the degree of rotation to the right or left from the vertical position. By rotating the disk, which acts as a chassis for the Bucky mechanism, we are able to bring the grid into proper position, as will be explained later.

The tube-carrying device is so arranged that any degree of shift is easily obtained in the cranial, caudal, ventral, or dorsal direction. The film-target distance is set at 30 inches, which, however, can be reduced to 20 inches if desired. The tube holder is provided with a stereoscopic shift, vertical and horizontal, or the degrees marked off on the tube carriage may be used for this purpose. The amount of shift is determined by dividing the target-film distance by 9 and using that factor. The opening, or window, in the disk is arranged to cover half of an 8 × 10 film. The cassette holder is attached to the orbit, which remains stationary, thus holding the film in unvaried position. When the tube is set at some angle other than the true vertical position, a circular disk or diaphragm, 5 in. in diameter, is placed in position (Fig. 2). This is ample size for sinus work, giving uniform position on the plate, or film, with no over-

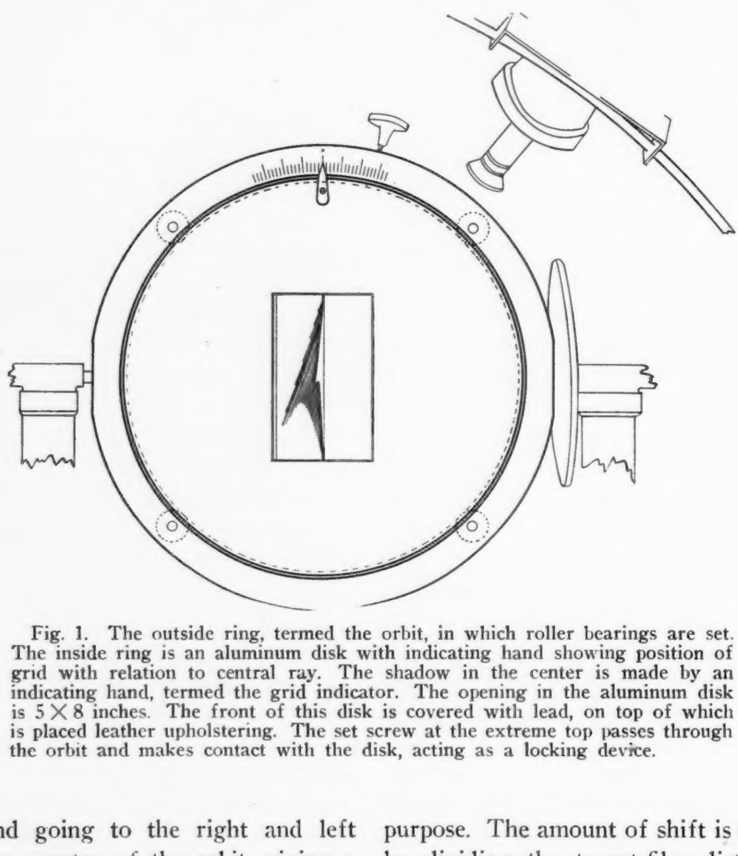

Fig. 1. The outside ring, termed the orbit, in which roller bearings are set. The inside ring is an aluminum disk with indicating hand showing position of grid with relation to central ray. The shadow in the center is made by an indicating hand, termed the grid indicator. The opening in the aluminum disk is 5 × 8 inches. The front of this disk is covered with lead, on top of which is placed leather upholstering. The set screw at the extreme top passes through the orbit and makes contact with the disk, acting as a locking device.

lapping in the exposures. It is this circular diaphragm which permits us to use the grid at various angles for making two uniform exposures on the same film. Should it be left out when one is operating at various angles, the exposures on the film will overlap.

The face of the disk, which is covered with leather, is marked off in such a way as to provide a convenient and accurate method of re-positioning the patient, enabling us to duplicate exposures at any time. At the top of the disk, near the outer margin, is a knob or handle which is used to rotate the disk conveniently. In this handle is a small level which allows us to set the disk absolutely perpendicular to the floor, when necessary. Slightly above this knob and to the left will be noted a set-screw in the orbit. This screw is used for holding the disk in proper position.

Figure 3, a back view of this device, is largely self-explanatory. The grid is not of the exact length desired but we did not wish to sacrifice any of its dimensions for this experimental work. As previously stated, it is a 1 to 4 ratio, 0.25 inch thick. Other ratios and thicknesses may prove of more value. The bell is arranged to signal both the beginning and ending of grid travel; about 0.5 inch of grid is moved at the first signal and about 0.5 inch remains to move at the end of the second signal. The assembly of the grid is on a cold-drawn brass rod which acts as a track to support the grid attached. The pump is so located that the piston acts for the opposite track. This arrangement, we think, might be greatly improved to reduce friction; nevertheless, it appears to run very smoothly.

A protractor for measuring the tube angles is attached to the axis line of the grid on the right side of the machine (Fig. 4), and works with the orbit and other parts of the device. The protractor is marked off in degrees starting at the top with 90°,

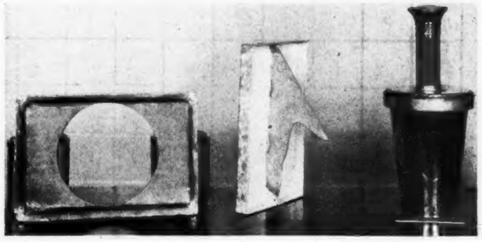

Fig. 2. The circle within the lead pan shown on the left is 5 inches in diameter and exactly covers one-half of an 8 × 10 film. This pan is needed only when using various tube angles. The pan in the center is called the grid indicator and is made of sheet metal somewhat resembling the hand of a sundial. On the right is a flashlight mounted in the center of a tin cap which fits over the cone, indicating the path of the central ray.

indicating the vertical position of the disk which carries the grid in relation to the tube. The degrees are then marked down on the protractor so that 0 indicates the horizontal position of the orbit in relation to the tube. Starting at 0 and going on around the protractor the tube will reach 90° (below) and again form a vertical position in relation to the orbit. The indicating hand is placed centrally on the tube arm. This arrangement permits us to tilt the grid either backward or forward from its vertical position without giving any attention to the degree of tilt, since this can suit the convenience of the patient when he is being examined. The tube arm indicator is brought to the 0 point of the protractor, and the central ray is then always perpendicular to the film. From this point we may raise or lower the tube arm to any degree of angulation we wish. The tube head carriage is also marked off in degrees, permitting the tube to move either to the right or left. For illustration, in making frontal sinuses we would tilt the disk away from the patient to any convenient position, bring the tube arm indicator to 0, and then elevate it 23°. The patient then is in the same position as though he were placed on a 23° angle board.

For the "G" line technic it is necessary only to position the patient's head properly

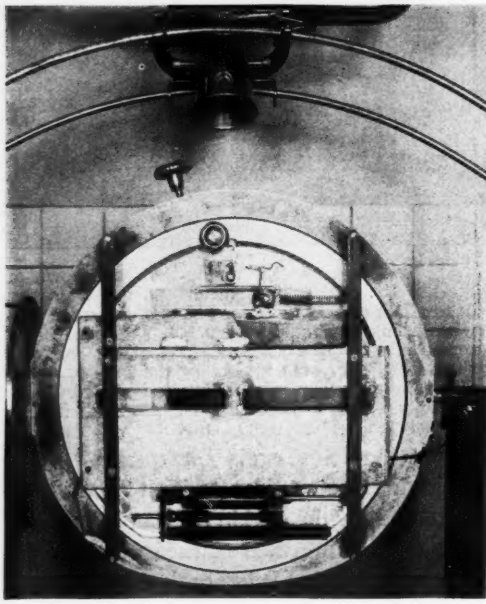

Fig. 3. Back view.

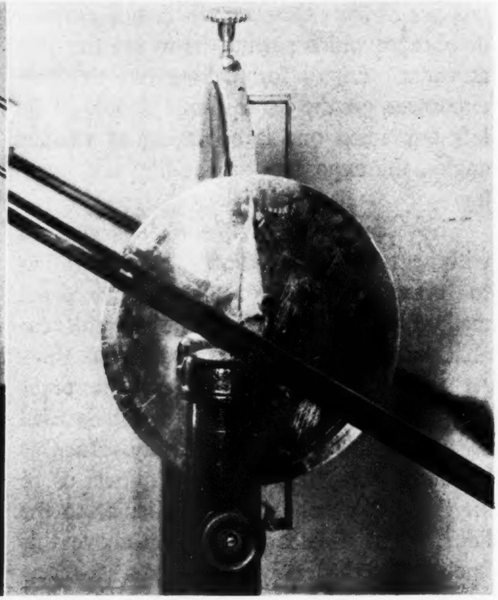

Fig. 4. When the grid is vertical, the large indicating hand on the side of the grid points to 90. This disk is fixed tight to the axis of the orbit. The indicating hand remains in a stationary upright position. When the orbit is tilted forward or backward, carrying the grid, this large indicating dial moves with it. Therefore, the horizontal line, 0, on the dial must, of necessity, follow the tilt of the grid. When the indicating hand as attached to the tube arm is brought to 0 on this dial, the central ray will be brought to the exact vertical position over the axis of the grid.

and bring the tube arm down exactly to the 17° mark below 0. The phrase "to position the patient properly" is of great importance in securing this position.

This arrangement is found very convenient and all work is accomplished with one indicator; at the same time, it releases the patient from the floor, so to speak, with reference to any angle (Fig. 5). The patient here is sitting in a comfortable position, while the head is actually inclined 15° away from the perpendicular plane. At the same time the target of the tube is directly perpendicular to the film, giving us a direct postero-anterior view in a much more convenient position than if the grid were set vertically and the patient compelled to assume a more erect position.

We might also mention that the central ray in any position of the tube always points to the exact center of the film. This technic applies to all positions of the head in which the ordinary flat Bucky grid is found practical. On the other hand, if we desire to use the numerous tube shifts and angles so often found necessary in the examination of the mastoids, optic foramen, temporomandibular joint, etc., and not found practical on the ordinary stationary grid, we will find that, with the aid of this device, we may conveniently do all head work requiring Bucky technic, dispensing with the interchangeable, or spiral, type of grid.

The method of finding the proper grid angle is simple for any position; when once found, this part of the technic can be dispensed with for similar examinations. Granting that you have never used this device and desire to use it with some position not found practical with the stationary grid,

you will first place your patient in position before the diaphragm; then set the tube at the angle you wish so that the central ray passes directly through the anatomic point to be examined. This will necessarily bring your central ray to the center of the film. Then have the patient step aside and place in the opening of the disk a small frame resembling the hand of a sun dial. This instrument we designate as the grid indicator (Fig. 2). By using a flashlight so mounted that it fits over the outside of the cone, as illustrated, you will note that the light falls on the grid indicator, casting a shadow to either side. This light indicates the path of the central ray. You will then release the set screw at the top of the orbit, permitting the dial which carries the grid and its mechanism to rotate either to the right or left as indicated, until the shadow cast by the dial indicator disappears from view. You will then note on the orbit the degree of rotation of the grid. Locking the dial in this position you are now ready for the exposure. This procedure we term "logging the grid"; it is unnecessary to repeat the process so long as you use the same position and the same angles. For illustration, you are making the right mastoid exposure and you have rotated the grid to 52°; for the left mastoid examination you will rotate the grid to 52° in the opposite direction, the patient assuming the same position with the left mastoid to the plate, and repeat the exposure. Figure 6 shows a stereoscopic view of the right mastoid, and Figure 7 is a view of the right mastoid. After the exposure was made the patient was asked to stand aside, the cassette was pushed into position Number 2 and a flash was made of the grid at its stationary position, giving the correct view of grid rotation for mastoid exposures in the double 13° angle.

As an additional aid in securing uniformity of position for duplicating parts on the film, there is, on the dial of the disk, a scale which may be used as a landmark with any point you may arbitrarily select, the glabella, external canthus of eye, tip of nose, angle of mouth, occipital protuberance, vertex, etc. By remembering the numeral (we will say 52) when one is using a double 13° position for the mastoid, it will not be necessary to repeat the logging process. A record of all exposures can be filed for future reference, making it easy to duplicate at any future time.

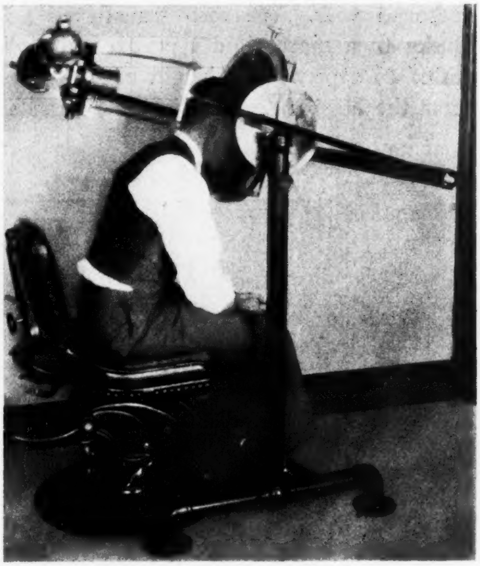

Fig. 5. The direct postero-anterior view is obtained from a convenient position.

We might also add that, when this device was finished, it was first mounted on an old dental chair purchased for the purpose. The base was removed from the chair and used as a stand on which to mount the Bucky arrangement, the idea being to permit adjustment for different heights. A swivel chair was used for seating the patient. However, we soon learned that the base of a dental chair with the parts attached allowed too much vibration of the mechanism, and the breathing of the patient was a factor to be

reckoned with. We then transferred the Bucky to a more rigid type of stand adjusted to a permanent height of 44 inches from the floor. We reassembled the dental chair and used it to adjust the height of the patient to the proper position (Fig. 5). This we found more convenient in many ways. We can easily stand at the back or side of the patient, and manipulate the chair with one foot while viewing the exact position.

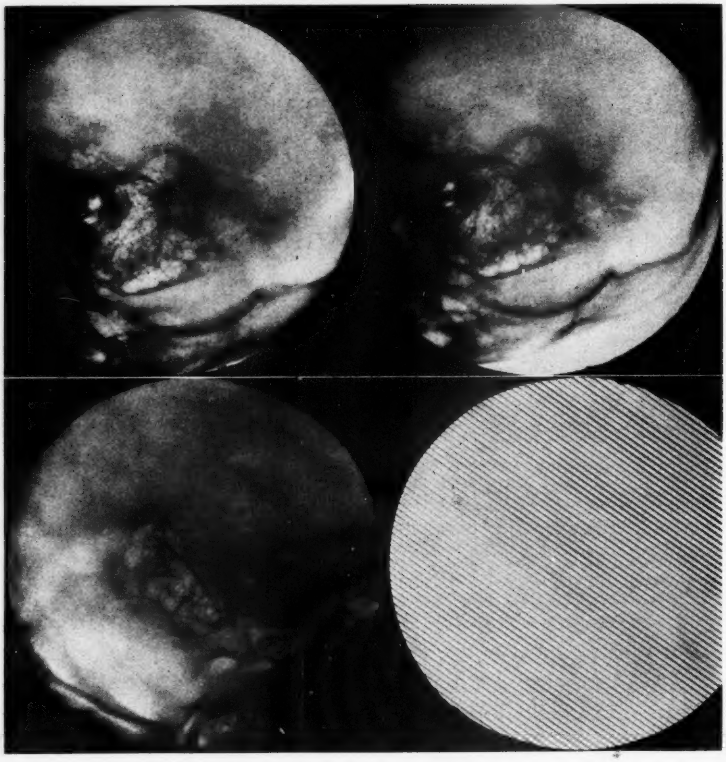

Fig. 6 *(top)*. A stereoscopic view of the right mastoid.

Fig. 7 *(bottom)*. A view of the right mastoid. After the exposure, the patient is asked to stand aside, the cassette pushed to position No. 2, and a flash is made of the grid at its stationary position, giving the correct view of grid rotation for mastoid exposure in the double 13° angle.

CONCLUSIONS

Some of the advantages of this device are:

1. The patient is seated in an upright and comfortable position.
2. The head can be placed and held in position without undue strain.
3. The tube can be shifted to any desired angle.
4. The central ray is always perpendicular to the center of the film.
5. Two exposures can be made on an 8×10 film, saving time and expense.
6. Stereoscopic shifts in two directions can be made which can be studied with a 75-cent hand stereoscope.

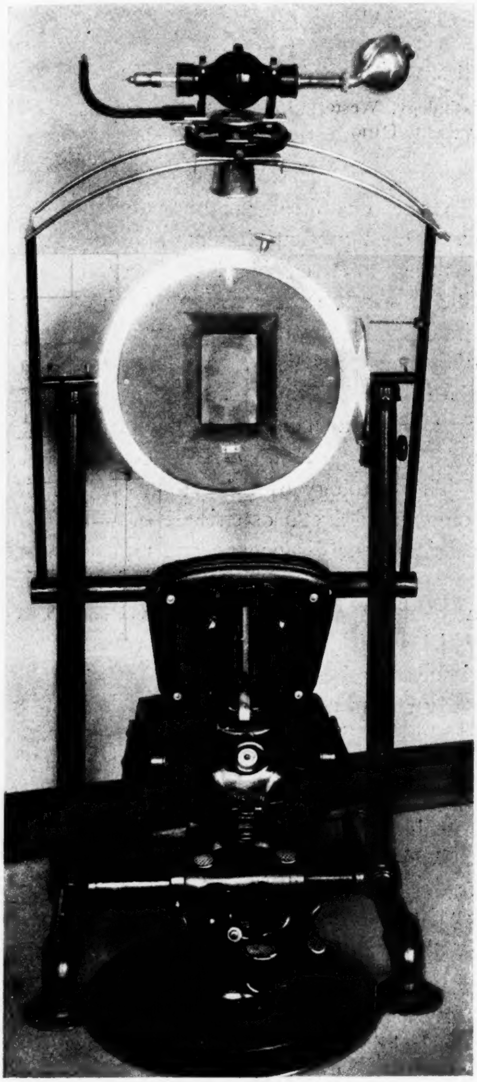

Fig. 8. Front view of machine showing leather-covered aluminum disk and general assembly of machine with dental chair hoist.

Fig. 9. A side view of machine with patient in position for mastoid exposure.

7. A single Bucky grid adapted to any tube angle, eliminating the spiral or interchangeable grids, is used.

8. The grid may be removed, or the cassette may be placed on the front of the dial, disregarding the grid if desired, still retaining all the advantages of any other sinus tube stand we know of at the present time.

9. A graduated dial is attached to the axis of the grid, disregarding the floor with reference to the position of the patient.

Since the discovery of the Potter-Bucky grid, its value has been a debatable question; yet to-day no X-ray laboratory is complete without it. That the use of the Potter-Bucky diaphragm, when applied to the examination of the skull, increases the definitive value of a film is a settled question with a large number of roentgenologists. But the theme of this paper has not to do with the value of the Bucky grid but to its adaptation to various angles, with special reference to the examination of the paranasal sinuses.

LEONTIASIS OSSEA[1]

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HYPEROSTOSIS cranii, craniosclerosis, or leontiasis ossea is a rare disease found most often in individuals in the early decades of life. It produces enormous, diffuse hyperostoses, beginning usually in the bones of the face and extending to those of the skull.

The term *leontiasis ossea* was given by Virchow (12). He noted the resemblance to the facies of leprosy and assumed the bony alteration to be of the same nature as elephantiasis of soft parts. Bockenheimer (2), who gives a complete review of the literature up to 1908, pointed out that a marked facial deformity is not always present, that local infectious disease is not a necessary precursor, that it is not similar to elephantiasis, and proposed the designation *diffuse hyperostosis of the face and skull.* The term *leontiasis ossea* is widely applied and can be employed by the rule of good usage.

In leontiasis ossea the cranial and facial bones are more or less markedly thickened, depending upon the stage of the disease. They give the impression of being swollen, but the resemblance to normal bone remains. The inner and outer tables cannot be differentiated. The homogeneous aspect may be interrupted by some scattered patches of soft fibrous looking material and, in rare cases, cystic degeneration of such fibrous patches may be seen.

The bone is vascular, soft, and can be cut away or penetrated easily with a trephine. In later stages, when ossification has advanced, it becomes more firm. The surface of the bone is smooth.

When examined anatomically, the diseased bone presents innumerable apertures, but there are areas in which fewer are seen. Such areas are the remains of the compact tissue. The apertures represent the surface of a cancellous tissue which has taken the place of the original bone and is permeated by a vascular connective or fibrous tissue medulla.

The histology of these forms is the histology of Paget's osteitis deformans. The original bone disappears, and an area much larger than that occupied by it is filled by a vascular and cellular connective tissue, which in places may become fibrous. In this tissue new bone develops, showing in the early stages no lamination, or a lamination produced differently from the ordinary. Around the lamellæ there is a row of spindle-shaped cells, representing osteoblasts. Few osteoblasts are found in the diseased tissue.

Reviewing the literature many cases were found in which, in accordance with Knaggs' (5) findings, the histologic picture was that of Paget's disease, but Boit (1) and others examined specimens of leontiasis microscopically and found the typical appearance of Recklinghausen's osteitis fibrosa cystica characterized by multiple cyst formations. The combination of these two forms also occurred at times.

From the histologic findings, leontiasis ossea can be considered as a localized form of either Paget's osteitis deformans or Recklinghausen's osteitis fibrosa cystica. Because the two diseases are very similar histologically, there is considerable difference of opinion at the present time as to whether Paget's and Recklinghausen's diseases represent different stages or manifesta-

[1]Read before the Radiological Society of North America at the Seventeenth Annual Meeting, at St. Louis, Nov. 30–Dec. 4, 1931.

tions of the same disease or whether each is a distinct entity. Both show fibrous tissue, cell-rich medulla, lacunar resorption, giant cells, osteoblasts, and changed bone lamellations. The differences are mainly clinical and roentgenologic. Osteitis fibrosa starts in childhood and, before the bone changes can be noted, there are aches in the bones, which gradually increase in severity. Pathologic fractures are common but the involvement of the skull is very rare. Paget's disease occurs in middle life and old age and the involvement of the skull is very common. No pathologic fractures occur.

Meyer-Borstel (8) published a case recently which seems to confirm the close relationship of the two diseases. The patient, first examined in 1920 when he was 24 years of age, complained of rheumatoid pain in the left knee, and the roentgenograms showed two small cysts in the patella. A year later almost all the bones showed multiple cyst formation with numerous pathologic fractures. In 1928 the cysts had disappeared, but the bones showed the typical appearance of Paget's disease, including the involvement of the skull, which previously had appeared normal. The author compares the different manifestations of Paget's and Recklinghausen's diseases with the manifestations of a metastatic breast carcinoma, which in some cases produces multiple, sharply defined, osteolytic, cystic destructions in the medullary portion, with severe pain and pathologic fractures. In other cases the metastatic tumors are represented as diffuse, osteoplastic, homogeneous eburnations of almost the entire skeleton with the patient in good physical condition.

It is readily seen from the above that leontiasis ossea is not a pathologic entity, but a clinical picture, the main symptom of which is a leonine face. It begins usually at an early age and one of the earliest signs is nasal obstruction. Trouble with the lachrymal apparatus from stenosis of the nasal duct is also to be expected. It is occasionally mentioned and, because it may occur before deformity appears, it has in some cases been looked upon as the exciting cause of the disease. It is difficult to determine exactly when the disease starts because the patients report only when the changes are marked.

Among the involved bones the most common are the nasal and zygomatic lower orbit, horizontal ramus of the mandible, and the alveolar processes of the lower and upper jaws. Among the skull bones, the frontal and temporal bones are most commonly involved.

The diseased areas, which are painless, show no evidence of inflammation. The slow progress of the bony changes is characteristic. At times the disease remains dormant for over a period of years and the patients have no subjective symptoms. There are, however, cases which are progressive in character. The process grows in the course of years and there is a constant enlargement in the size of the bones.

In some cases neuralgic pains occur early in the disease, due to the obliteration of the supra- and infra-orbital foramina. In other cases speech and mastication are disturbed. The progressive stages of the disease of the skull bones are serious. Narrowing of the orbital cavity may occur, with protrusion of the eyeball and subsequent disturbance in vision, amblyopia, and finally blindness. If the base of the skull is involved, the cranial nerves may be affected with resulting disturbances of smell, taste, and hearing. Even paralysis of the extremities may occur. In the end-stage, severe headache, delirium, and attacks of cramps may be present. Consequently, the course of the disease is variable. Whereas the mild cases present no other symptoms than the deformity, in others the disease can be fatal through rapid progression. In hogs, apes, cows, horses, dogs, and rats the veterinarian often finds

pathologic changes of hyperplastic nature in the jaw and the bones of the forehead very similar to the human leontiasis ossea.

The etiology of leontiasis ossea is not known, but many theories are advanced.

Knaggs (5) thinks that the most probable cause is a micro-organism. The infection, according to him, travels under the periosteum and sets up an osteitis of the adjacent bony tissue. A sinus infection, infection of the nasal cavity, or an infected tooth apex could be the primary focus. There is, however, no bacteriologic proof that leontiasis ossea is due to a micro-organism. The suggestion of micro-organismal origin is based upon the curious way in which the disease spreads. In Léri and Arnaudet's (6) case, there was a history of a purulent discharge through a fistula of the left side of the maxillary bone with a tremendous bilateral enlargement of the bone. That infection plays a possible rôle is suggested by the fact that at times an entire herd of hogs becomes diseased, and in horses chronic joint changes were found associated with facial changes.

Recklinghausen (9) thought trauma to be an important primary factor of leontiasis because trauma often leads to subsequent new bone production. And in fact, a history of trauma is frequent in the clinical records of the published cases.

Ziegler thinks that the disease is due to a congenital disposition of the periosteum and marrow to grow. There are theories that the disease has something to do with persistent thymus or hypophyseal disturbances. Some autopsied cases, however, did not show changes in the thymus, thyroid, or hypophysis. In some cases heredity can be established as a factor in the etiology of this condition.

The roentgenologic findings are characteristic: Deforming enlargement of the bones, narrowing of the medullary portion throughout localized areas of the skull and face, secondary narrowing of the foramina, orbits, and sinuses. The details of the bone, however, vary according to the underlying pathologic process, showing either a pagetoid lamellation, with osteoid tissue formation and lacunated areas, or multiple cysts corresponding to Recklinghausen's disease.

The roentgenologic diagnosis can be made before clinical symptoms appear. Although it is generally recognized that the condition is localized to the facial bones and to the cranium, Ruppe (10) found that the first and second cervical vertebræ, and Knaggs that the head of the fibula, may be also involved, indicating that the lesion is of more generalized character.

Malignant tumors resemble leontiasis ossea only in the beginning because bone tumors grow very rapidly and the roentgenograms show bone destruction. Syphilis, which as a rule produces a diffuse, but never as marked, hyperostosis, occurs more often in the bones of the skull than of the face. Also there are usually other signs of hereditary syphilis or syphilitic changes. Elephantiasis and lymphangioma are easily differentiated.

Osteomas form circumscribed, well defined bony tumors, which are at times connected by a stem to the bone from which they originate. They consist of eburnated and not of spongiose or fibrous tissue.

Acromegaly starts at the end of the growing period, first with the extremities, then the face. Although acromegaly can produce the same kind of thickening of the facial and cranial bones, with obliteration of the paranasal sinuses, the differentiation is easy. In acromegaly, not only the bone tissue, but all the tissues of the face, take part in the excessive growth, the lips and tongue being also markedly enlarged.

The prognosis in leontiasis ossea is favorable when the disease shows a slow growing tendency. Progressive cases are hopeless. If the disease is well localized in an early

stage, good results may follow operation. Cases are reported, however, in which a rapid growth occurred after operation. Consequently, it is hard to determine whether or not the patient should be operated upon. If the surgeon is forced to operate on account of the pain and disfiguration, it can be done on facial bones, but the skull bones should never be touched.

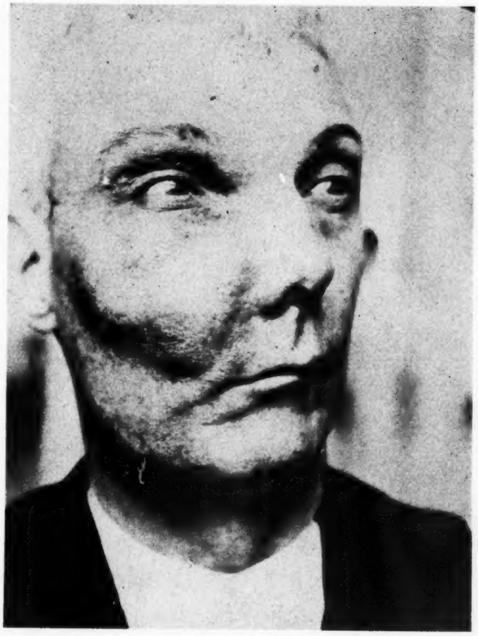

Fig. 1. Photograph showing the marked, irregular enlargement of the right zygoma, frontal, and maxillary bones and of the mandible. The mouth is drooped, the nose is tilted to the left, and the outer circumference of the orbital cavity is narrowed.

CASE REPORT

P. H., 57 years old, white, male, was admitted to Cleveland City Hospital on May 21, 1928, in a stuporous condition. He had suffered from restlessness, nervousness, and general irritability for years. About three weeks previous to the present examination, he was told by his doctor to take "bromidia." The day before admission the patient took the equivalent of 270 gr. of chloral hydrate within a period of 17 hours. He passed into coma at home and was sent to the hospital by his physician.

Following an injury to the right cheek in boyhood at the age of 12, a swelling of the right cheek bone was noted. This had slowly and painlessly continued to enlarge. The increase had been very slow in the preceding decade. The wife stated that the patient had no venereal diseases or serious illness, but that he was addicted to alcohol and had attempted suicide on several occasions. The patient had always been nervous, but had become more irritable in the few months preceding the present illness. Amblyopia had been present of late.

The clinical examination revealed an irregular nodular enlargement of the right zygomatic arch, hard palate, maxillary bone, and right half of the mandible (Fig. 1). The area of over-growth was not tender, nor was the overlying skin inflamed. There was a drooping of the right lid and right angularis iris. Tongue and fauces were negative. The urine showed nothing of interest. The white blood count was 8,000; the blood Wassermann was negative.

Roentgenograms (Figs. 2 and 3) showed the right frontal bone and the bones of the right side of the face, including the right mandible, to be tremendously enlarged. The process extended into the right temporal and sphenoidal bones, and the floor of the anterior cranial fossa was involved. The frontal bone in the region of the sinus measured 5 cm. in thickness. The enlarged bones showed multiple small and irregular areas of diminished density, surrounded by irregular areas of new bone production, giving a flabby, cottony appearance. There was marked narrowing of the right orbit and complete obliteration of the right frontal maxillary and ethmoidal sinuses, due to the overproduction of bone. The bone changes were both osteoclastic and osteoplastic in

Fig. 2. Postero-anterior view of the skull and face. The right maxillary, frontal, and zygomatic bones and the mandible retain their original form, but are tremendously enlarged. The frontal and maxillary sinuses, the ethmoidal cells, and the nasal cavity are all obliterated on the right. The right orbit is narrowed. There is considerable new bone formation throughout, with lacunar areas of bone destruction. The destructive changes are most marked in the mandible.

Fig. 3. Lateral view of the skull and face showing the unusual thickness of the frontal bone. The process involves the sphenoid bone also. The sphenoid sinus is almost completely obliterated. Note the marked protuberance of the right maxillary bone.

character. The roentgenologic appearance was very suggestive of Paget's disease.

The patient left the hospital at the end of three days and was not seen again.

CONCLUSIONS

1. Leontiasis ossea is a clinical descriptive term and not a pathologic entity.
2. The histologic picture is either that of osteitis deformans (Paget) or of osteitis cystica (Recklinghausen).
3. The case reported showed the roentgenologic appearance of osteitis fibrosa (Paget's disease).

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DISCUSSION

Dr. Freedman (opening remarks): This is not a histologically proven case. Unfortunately, as the patient was not co-operative, we were unable to obtain a biopsy on him, nor was he willing to return for further check-up. But I think the roentgenologic appearance, clinical history, and facial deformity are sufficient proof to consider this a typical representative of leontiasis ossea.

One of the main reasons that we roentgenologists do not see this type of lesion more often is that the disease commonly starts in the region of the maxillary sinus and alveolar process, and the dental surgeons are consulted first. Although the disease is considered a rare one in the medical literature, I encountered in Cleveland recently three additional cases, which had been seen and roentgenographed by dentists.

Dr. Leon T. LeWald (New York): I am much interested in this presentation because of its possible relationship to Paget's disease. My impression is that, although it certainly has many of the characteristics, it is somewhat different in nature from Paget's disease.

I have studied 69 cases of the latter and, curiously enough, there is not a single one in that group which shows the peculiar involvement of the bones of the face that is seen in leontiasis. Four cases do show marked involvement of the superior maxilla, and one case presented a marked involvement of the inferior maxilla, but none of them shows extreme involvement of all the bones of the face.

Did I understand Dr. Freedman to say that no other bones of the body are involved in these reported cases?

Dr. Freedman: Yes, other bones of the body have been found to be involved also. Ruppe found the involvement of two vertebral bodies and Lawford Knaggs found the involvement of the fibula. The involvement of the additional bones of the skeleton are most often of the pagetoid type.

Dr. Robert J. May (Cleveland, Ohio): The pathologic process noted in leontiasis ossea is a marked thickening and, later in the disease, a marked increase in the density of the bones of the face and skull. The cranial bones often attain a thickness of 3 cm. or more. Such a skull may weigh 10, or more, pounds.

Knaggs describes two forms: (1) a creeping periostitis which, he says, is due to some sort of infection, and (2) diffuse osteitis due to toxemia.

Schüller states that both forms of the disease are present in most cases. Atypical forms of the disease may involve one, or several bones, or only a small part of one bone.

In the first form, the periostitis begins in the nasal fossæ, spreading to the accessory nasal sinuses, orbits, and bones of the face and skull. The spaces gradually become filled with new bone, the decreased orbital capacity causing bulging of the eyeballs. The foramina are narrowed and the nerves, vessels, etc., emerging through them, are compressed. Headache, blindness, neuralgia, convulsions, and the other symptoms are due to pressure on the structures as they emerge from the foramina and from the increased cranial pressure due to the decrease in the size of the cranial cavity.

Knaggs believed that infection or toxemia causes the disease. Other writers have suggested syphilis as a rather infrequent cause. Friederich cites several cases of Hodgkin's disease in which he found similar bone deformities. Trauma and disturbed internal secretions are also regarded as etiological factors. The histologic changes in leontiasis ossea, osteitis deformans, and osteitis fibrosa cystica are the same and it is probable that all three are different manifestations of the same disease.

Surgical and medical treatment are disappointing. I wish to cite briefly one case with osteitis fibrosa cystica limited to the frontals and sphenoids which improved under roentgentherapy.

Five years before the patient presented himself for examination, he had suffered a fracture of the right side of the skull, the exact site of which was not known. For two years he had noticed a painless swelling of the right

(Continued on Page 55)

TRANSIENT K.V.P. AND r OUTPUT FROM AN AIR-COOLED THERAPY TUBE

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IT is the purpose of this paper to call attention to a little known X-ray tube phenomenon which, while possibly not very important once it is understood, can cause considerable bewilderment if it is encountered without a knowledge of its explanation. The phenomenon takes place in any air-cooled therapy tube during the heating-up period of operation (while the anode and glass of the tube are coming to a steady state of temperature). Even though the primary voltage and milliamperage, or peak kilovoltage and milliamperage, are kept constant, it makes itself known by a changing r output. Since air-cooled therapy tubes are now developed to the point at which they can be used at full voltage without first going through a long warming-up process, the transient during this period, unless taken into consideration, can be a source of error in dosage large enough to be significant with present-day methods of measurement.

DATA

Data on both kenotron and mechanically rectified equipment show that operation of an air-cooled therapy tube at constant primary voltage and milliamperage during the heating-up period gives a change in kilovoltage which may amount to a rise of as much as 12 K.V.P., and a drop in r output which may amount to 15 per cent (as measured through 0.5 mm. of copper and 1 mm. of aluminum). The changes, which are of the same general order of magnitude on either equipment, are influenced by a number of factors: the temperature of the glass at the start, the milliamperage, the amount of circulation of air around the tube, the tube used, the equipment, and the line voltage wave shape. It will be noted that, for constant primary voltage, the r output drops, even though the K.V.P. rises. Attention is called to this seeming contradiction to point out that the r drop would be even greater were the K.V.P. held constant during this period.

The changes mentioned above occur to a greater or lesser extent with any tungsten anode air-cooled therapy tube. Different type tubes from various manufacturers have been tried. It might be noted at this point that the transient phenomenon does not occur with water-cooled type therapy tubes. In this type, heat is taken out through the water, the glass envelope does not change appreciably in temperature, and K.V.P. and r output are constant from the start. It should also be emphasized that the transients in the air-cooled tubes last only while the glass envelopes of the tubes are coming up to a steady temperature. After this is reached, the K.V.P. and r output are constant reproducible quantities.

With a thick pyrex glass tube, the transient period in general covers the first seven to ten minutes of operation from a cold start. It may last longer, if the tube is operated at low current, 2 or 3 ma., for instance. In any case, the changes take place more rapidly in the first few minutes so that, after five minutes, the tube voltage is not likely to rise more than 4 K.V.P., or the r output drop more than 6 per cent—if this much. The data given apply to operation from a cold start. If the tube is warm to start with, as it would be if operated within the preceding 15 minutes, the changes given will be cut in half—or less.

The transient is noticeable with the older,

thin, soft glass therapy tubes, although not to the same extent as with the newer, thick, pyrex tubes. The hard glass not only makes for greater change during the heating-up period, but the thicker glass which is used causes the heating-up period to last longer, and the better electrical operation of the tube causes it to be operated at full voltage sooner after a cold start. With the older, soft glass tube, the K.V.P. may rise as much as 10 K.V.P., or, in some instances, even drop 3 or 4 K.V.P., but the r output always drops—from 0 to 7 per cent. Stable conditions are reached in approximately five minutes.

The phenomenon that has been described apparently occurs with operation on any type equipment except constant potential and polyphase circuits that are nearly constant potential. On constant potential equipment, no change in K.V.P. or r output occurs during the heating-up period; and, as far as outward results are concerned, the phenomenon does not take place. As a matter of fact, however, the same changes take place inside the tube that are responsible on other circuits for the outward changes that have been discussed.

THEORY

Although the facts reported may seem unintelligible or even contradictory, fortunately an explanation can be given that makes them understandable. It is necessary first, however, to discuss a tube characteristic which, on the surface, may not seem related to the facts under consideration.

In any X-ray tube, not alone the air-cooled type, the bulb, or envelope, surrounding the anode and cathode is bombarded by electrons from the cathode. If there were no leakage of electrons from the bulb to the positive electrode of the tube, this bombardment would stop almost instantly when the bulb reached a negative potential sufficient to repel further electrons. A certain amount of leakage always occurs because glass, like every other insulator, has a small, but in this case important, electrical conductivity both over its surface and through its volume. As a result, there is a constant bombardment of electrons on the glass just sufficient to equal the leakage and the bulb takes on such a negative potential with respect to the anode that this equilibrium exists.

The amount of current that passes from cathode to anode potential by way of the bulb is negligible in itself, inasmuch as it amounts to only a current of the order of micro-amperes, or less. The fact, however, that the bulb is charged to a negative potential with respect to the anode, and can act as a grid in influencing the main electron flow between cathode and anode, is potentially important. *Potentially* important, because it is important only when its influence is a variable, as is the case in the air-cooled therapy tube.

Variability in grid action of the bulb in an air-cooled therapy tube while the glass is rising in temperature is a result of electrical conductivity change paralleling the temperature change, with consequent equilibrium change between leakage and bombardment and, therefore, changed bulb potential. In other words, with rising temperature there is more conductivity, the bulb becomes less negative, and grid action is reduced.

It remains to be shown what connection variable grid action of the bulb can have with the variable r output and K.V.P. phenomenon.

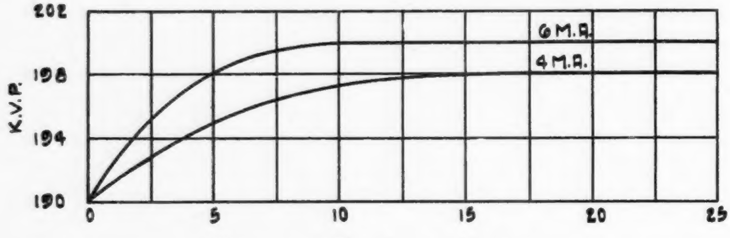
Ordinarily electron flow in a hot cathode X-ray tube is determined almost entirely by filament emission—the space charge voltage necessary to pull the electrons across being small compared to the operating voltage. The effect of the grid action is to increase considerably the space charge voltage so that the electron flow is to a greater extent influenced by tube voltage.

On any rectified circuit, where the tube voltage pulsates from zero to a maximum, the result is a slightly more peaked current wave shape than would otherwise be the case. The change in current wave shape, in turn, means that, for a given average (meter reading) milliamperage, the current useful in producing the hard X-rays (that pass through 0.5 mm. of copper) is increased. In addition, a more peaked current wave shape on practically all circuits gives a flatter topped voltage wave shape, that is, a voltage wave of lower peak value but of higher effective value.

On constant potential equipment, current wave shape is, of course, fixed and cannot be influenced. At the most, all that can occur is that a slightly higher filament emission may be necessary for a given tube milliamperage than would otherwise be the case.

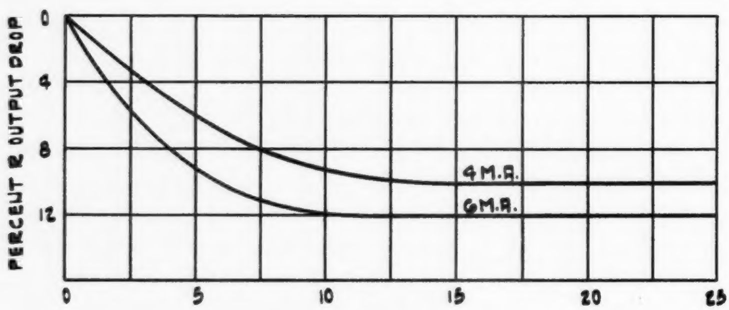
With this background, the sequence of events that results on pulsating voltage circuits in an increase in K.V.P. and a lowering in r output during the heating-up period can be outlined as follows:

Rising glass temperature gives (1) increased conductivity of the glass; (2) changed equilibrium between electron leakage and bombardment of the tube envelope; (3) less negative voltage on that portion of the envelope surrounding the anode-cathode space; (4) decreased grid action of the en-



Minutes operation from cold start

Fig. 1. K.V.P. transient from a thick pyrex glass air-cooled therapy tube operating on either a kenotron or mechanically rectified equipment at constant ma. and primary voltage.



Minutes operation from cold start

Fig. 2. r output transient (0.5 mm. Cu—1 mm. Al filter) from a thick pyrex glass air-cooled therapy tube operating on either a kenotron or mechanically rectified equipment at constant ma. and primary voltage.

velope, or bulb; (5) increased tendency for the tube current to be controlled by filament emission, rather than grid action space charge; (6) flatter-topped current wave shape, because the current is more independent of voltage; (7) changed voltage wave shape, usually in the direction of a more peaked wave; (8) decrease in filtered r output. Any increase in K.V.P., as far as influencing filtered output is concerned, is more than counteracted by the drop in peak milliamperage and decreased length of time during which both are reasonably high.

No attempt will be made here to prove rigidly the above explanation. It may be interesting, however, to mention a few additional facts bearing on it.

If the bulb of an air-cooled therapy tube, before being operated, is heated mechanically by means of an oven or gas flame to approximately the steady running temperature, no transient is present from the start of operation, thus showing that temperature change is the controlling factor in the transient.

Those who have used both the older, lime glass, water-cooled therapy tube and newer, thick, pyrex glass tube have probably noticed that for the same primary voltage the hard pyrex glass tube gives a lower kilovolt peak. The reason for this lies in the fact that the hard glass has a lower glass conductivity than the soft lime glass. The bulb, therefore, charges up to a more negative potential, grid action is more pronounced, the current wave shape more peaked, and the voltage wave shape flattened. The difference in current wave shape between the two types of tubes is observable by means of stroboscopic analysis of a neon glow tube in series with the X-ray tube, or by oscillographic study.

In a kenotron, any grid action of the negatively charged walls is a very serious thing, because the tube voltage drop, which in this case is entirely determined by the space charge voltage, must be low and reproducible. It was this consideration that led to the development of the cylindrical anode type kenotron in which the anode completely shields the anode-cathode space from any possible grid action of the glass bulb.

SUMMARY

During the heating-up period of operation of an air-cooled therapy tube, the K.V.P. and r output are almost certain to be variable quantities.

This is true for operation on all equipment except constant potential.

The tube voltage may rise for constant primary voltage as much as 12 kilovolt peak. The r output always drops—in some cases as much as 15 per cent.

With a thick, hard glass therapy tube, the transient period covers the first seven to ten minutes of operation from a cold start.

The explanation for the above is wave shape change caused by decreasing grid action of the bulb of the tube as the glass envelope rises in temperature.

AN INVESTIGATION OF THE GASEOUS DECOMPOSITION PRODUCTS OF X-RAY FILMS[1]

By GRACE BALLARD, Mount Sinai Hospital, MILWAUKEE, WISCONSIN

THE original purpose of this investigation[2] was to determine the decomposition temperature of nitrocellulose X-ray films and the toxic gases evolved from decomposing nitrocellulose and cellulose acetate films. The analysis of the gases was limited in this work to the determination of their hydrocyanic acid content. The concentrations of the other toxic constituents, namely, carbon monoxide and the oxides of nitrogen from nitrocellulose films and carbon monoxide from cellulose acetate films, have been well established by other investigators.

The base of a nitrocellulose X-ray film consists of a mixture of nitrocellulose and camphor similar to celluloid. The camphor imparts plasticity to the mixture. The base of the film is covered on both sides by a thin layer of gelatin impregnated with silver bromide. The explosiveness of nitrocellulose is in direct proportion to the degree of nitration of the cellulose. In films the nitrogen content of the nitrocellulose is about 11.7 per cent, whereas it is as high as from 12.4 to 13.5 per cent in explosives such as guncotton and smokeless powder (1). Films in which the nitrocellulose base is replaced by cellulose acetate are called "safety" films, because the cellulose acetate is stable at temperatures at which nitrocellulose decomposes.

Celluloid burns only when brought in contact with a flame (2). Flameless decomposition will take place, however, if a sufficiently high temperature is attained, in which case the celluloid decomposes with the evolution of large quantities of gases. According to Worden (2), gases are given off which form explosive mixtures with air. These gases, the products of incomplete combustion, are formed in a limited supply of oxygen. They consist mostly of carbon monoxide, nitric oxide, methane, and hydrogen, and combination with oxygen takes place when they come in contact with air.

Although nitrocellulose at room temperature will not decompose to the point of combustion, some deterioration takes place. Worden says that nitrogen peroxide is liberated when nitrocellulose is stored. Farmer (3) explains the decomposition of nitrocellulose as follows: "A catalytic decomposition can take place in the presence of nitric peroxide. It occurs in the absence of moisture and accelerates itself autocatalytically. It consists of an internal oxidation of the nitric ester, aided by atmospheric oxygen, which re-oxidizes nitric oxide evolved by the nitrocellulose to the nitric peroxide. This is absorbed by the nitrocellulose and causes further decomposition."

Experiments undertaken by the Chemical Warfare Service (1), in its investigation of the conditions incident to the disaster at Cleveland, show that "X-ray film, if stored in large quantity, will decompose if subjected to a temperature of 100°C. or higher. The decomposition point for periods of heating not exceeding several hours is near 135° C. At higher temperatures, the decomposition becomes more and more rapid and takes place within one minute or less at about 160°–170° C." It was also found that contact with an electric light bulb for less

[1]Read before the Radiological Society of North America, at the Seventeenth Annual Meeting, at St. Louis, Nov. 30–Dec. 4, 1931.

[2]The experimental work herein reported was done under the direction of Dr. Herbert Heinrich, of Marquette University, whose helpful suggestions have proved invaluable.
Appreciation is extended to the American Medical Association for its grant, and to the Wisconsin Radiological Society for its help in defraying expenses.

than ten minutes will start decomposition of films, and that ignition of X-ray films by direct contact with steam pipes takes place readily. However, a jet of live steam at 75 pounds pressure did not start combustion when it was directed on envelopes containing films. Cellulose acetate, or "safety films," did not decompose under the conditions under which nitrocellulose films did. These results of the Chemical Warfare Service were corroborated by Braidech and Saylor (4), who found that films held in contact with a 100-watt bulb ignited in from two to seventeen minutes.

The reports of other investigators clearly show that both carbon monoxide and the oxides of nitrogen are evolved in large quantities from the decomposition of nitrocellulose films. An analysis of the gaseous products of decomposition of photographic films was made by Hall and Snelling (2). Their results are as follows:

	A.—*In vacuo* Per cent	B.—*In pleno* Per cent
Walter soluble	3.7	0.7
Nitrogen dioxide (N_2O_2)	28.5	
Carbon dioxide	7.3	7.7
Carbon monoxide	26.3	41.2
Hydrocarbons	0.7	3.1
Nitrogen	31.5	26.3
Oxygen		2.1
Hydrogen		18.9

The results obtained by Dr. Veazey (4) from his analysis of the gases obtained from the decomposition of nitrocellulose X-ray films are as follows:

	A.—Insufficient air for complete combustion Per cent		B.—Atmosphere of carbon dioxide Per cent	
Nitric oxide	35.6	34.0	58.2	60.9
Carbon monoxide	34.0	35.2	38.3	36.2
Hydrocyanic acid	0.86	1.0 Residue	3.5	3.0

In a separate determination, 1.3 per cent of hydrocyanic acid was obtained.

The Chemical Warfare Service summarizes the results obtained from the flameless decomposition of nitrocellulose X-ray film, separated by paper, as follows:

	Per cent
Nitrogen dioxide ($NO_2(N_2O_4)$)	6.9– 8.9
Nitric oxide (NO)	1.4– 8.2
Carbon monoxide (CO)	47.4–59.1
Oxygen	None
Carbon dioxide	21.3–24.5
Hydrogen	0.9– 3.2
Methane	1.0– 2.7

Olsen, Brunjes, and Sabetta (5) decomposed uncoated nitrocellulose X-ray film in an atmosphere of gas obtained from a previous experiment, obtaining the following results:

	Per cent
Carbon dioxide	14.8
Carbon monoxide	34.1
Hydrogen	0.4
Nitrous fumes	38.0
Hydrocyanic acid	0.23
Methane	2.4
Nitrogen	10.7

Few analyses have been made on the gases evolved from burning cellulose acetate films, undoubtedly due to the fact that their fire hazard is no greater than that of other cellulose material, such as wood or paper. There is, moreover, little danger of poisonous gases being evolved from them. If the films are burned in a limited supply of oxygen, carbon monoxide will undoubtedly be present, as it is formed when wood or paper are burned under such conditions. Olsen and his co-workers obtained 42 per cent and 49 per cent of carbon monoxide from uncoated cellulose acetate films burned in an atmosphere of nitrogen, and 34.4 per cent from cellulose acetate film with the gelatin coating. When the same films were burned in an excess of air, from 5.3 per cent to 7.9 per cent of carbon monoxide was found. When ordinary newspaper was burned under the same conditions, 38.1 per cent of carbon monoxide was obtained in an atmosphere of nitrogen, and 6.2 per cent in an excess of air.

In view of the work of other investigators, Dr. H. B. Podlasky thought it might be advisable to limit this investigation to the

possibility of hydrocyanic acid being evolved in toxic quantities. The instantaneous character of some of the deaths at the Cleveland Clinic, mentioned by Dr. Nichols at a meeting of the Radiological Society, suggested to Dr. Podlasky the possibility that hydrocyanic acid might have been responsible or partly responsible for these deaths.

Comparison of the lethal doses of carbon monoxide, of the oxides of nitrogen, and of hydrocyanic acid is rather difficult due to the difference in their action. According to Henderson and Haggard (6), "Nitrous fumes are the most insidious of all of the irritant gases." Little discomfort is experienced at the time of exposure, but several hours later, sometimes as long as 24 hours afterward, edema of the lungs develops and the individual dies.

Carbon monoxide and hydrocyanic acid are asphyxiant gases (6). Hemoglobin has a strong affinity for carbon monoxide, in fact, three hundred times its affinity for oxygen. Hence, exposure to carbon monoxide results in a carbon monoxide hemoglobin being formed. Thus, the oxygen-carrying power of the blood is reduced, resulting in asphyxia. Hydrocyanic acid produces asphyxia in a different manner. It is a protoplasmic poison acting directly on the cells, interfering with tissue or internal respiration. In severe asphyxia, unconsciousness develops at once, and the individual falls as though struck by a blow on the head. If the asphyxia continues, he dies in a few minutes.

Henderson and Haggard give the following fatal concentrations of the three gases:

Carbon monoxide—1,500–2,000 parts per million are dangerous for an exposure of one hour.
4,000 parts per million, and above, are fatal in exposures of less than one hour.

Nitrous fumes—117–154 parts per million are dangerous for a short exposure.
240–775 parts per million are rapidly fatal for a short exposure.

Hydrocyanic acid—120–150 parts per million are dangerous in from thirty minutes to one hour.
3,000 parts per million are rapidly fatal.

Hydrocyanic acid, therefore, is considerably more toxic than carbon monoxide, although less so than the oxides of nitrogen. Immediate deaths are usually attributed to carbon monoxide rather than the oxides of nitrogen. Irvine (7) says, "Nitrous fumes never, in our experience of ordinary gassing accidents, produce partial or complete unconsciousness at the time of exposure as does carbon monoxide, although they may do so if present in massive amounts, and cases of rapid deaths from the concentrated fumes of burning explosives may be partly due to this cause."

Statements found in the literature indicate that hydrocyanic acid may be formed from the combustion of nitrocellulose. Worden says that a little hydrocyanic acid is evolved when celluloid is heated in the absence of air, or in an insufficient supply of air. Brunswig (8) says, "The products of the explosion of nitrocellulose contain . . . in cases of incomplete transformation, nitrogen dioxide and hydrocyanic acid." Hamilton (9) quotes Kockel as saying, "Eight deaths in a burning celluloid factory in Leipzig in 1900 were due to fumes of hydrocyanic acid." Kockel obtained 0.05 gm. of hydrocyanic acid from 5 gm. of burning celluloid. Others (6) also state that hydrocyanic acid is evolved when celluloid is burned.

There appears to be some difference of opinion as to whether or not hydrocyanic acid might have been evolved in toxic quantities in the disaster at Cleveland. Dr. Veazey (4) obtained 0.86 per cent and 1 per cent of hydrocyanic acid in his analyses made with insufficient air for complete combustion. As 0.3 per cent is rapidly fatal, the concentrations he found are in excess of the lethal dose. The Chemical Warfare Serv-

ice, however, did not find any hydrocyanic acid liberated from small amounts of film. In an analysis of the gases liberated from 16 pounds of film, separated by paper, 0.014 per cent of hydrocyanic acid was found. This amount is "negligible from a toxicity viewpoint compared to the amounts of carbon monoxide and the oxides of nitrogen found in the same samples." The analyses made, however, were not on concentrated fumes, but on fumes which were more or less diluted with air. Brown (10) does not mention hydrocyanic acid as one of the gaseous products of the decomposition of X-ray films. "Popular Science Monthly" (11) states that blood tests on the victims of the Cleveland disaster showed effects of hydrocyanic acid. Olsen and his co-workers obtained 0.23 per cent of hydrocyanic acid from uncoated nitrocellulose film decomposed in an atmosphere of gas from a previous experiment.

As the gelatin used in the coating of films is a nitrogenous substance, it appears possible that hydrocyanic acid might also be liberated from cellulose acetate films. Olsen and his co-workers obtained 0.75 per cent of hydrocyanic acid from a cellulose acetate film decomposed in an atmosphere of nitrogen. They obtained 0.4 per cent from the same film after the gelatin coating had been removed. An analysis by the Kjeldahl method on this film showed that 0.34 per cent of nitrogen was present. They did not obtain any hydrocyanic acid, however, from a different sample of uncoated cellulose acetate film.

STABILITY TESTS

Experiments were performed to determine the decomposition temperature of nitrocellulose X-ray films. A hot air bath was made by placing a large pyrex tube, 2.3 × 20 cm., in a beaker containing hot paraffin. A small piece of film was fastened directly on the bulb of a thermometer, which was then suspended in the tube. In general, it might be said that a small piece of film will decompose at about 150° C.; wide variations from this temperature, however, were obtained by varying the manner of heating. It was possible to decompose the film at temperatures as low as 70° C. and 65° C. by suddenly subjecting it to a very great heat. This was accomplished by plunging the tube containing the film and the thermometer, which were all at room temperature, into the hot paraffin bath, which was at a temperature of about 250° C. The film decomposed in from 30 to 40 seconds; that is, it took that length of time for the temperature of the film to be raised from room temperature to the temperature of decomposition, in this case from 65° to 70° C. (The possibility of these low temperature readings being partly due to the lag of the mercury in the thermometer was ruled out by tests to ascertain the speed at which the mercury thread could travel. It was found that, when the thermometer was plunged into the hot paraffin bath, the mercury rose from room temperature to 70°C. in 1.4 second.) On the other hand, if the film were heated very slowly, at the rate of about one degree a minute, a temperature of 250° C. could be reached without sudden decomposition occurring. However, in this experiment the film became black, brittle, and swollen. A small piece of film placed in contact with a 50-watt electric light bulb decomposed in from one and one-half to seven minutes. No perceptible difference could be found between the decomposition temperature of a film eight years old and of a recently used film.

It was thought desirable to test the stability of cellulose acetate films. Film, weighing 153.65 gm., cut into pieces from two to three inches square, was placed in a large desiccator. The latter was kept in an electric oven at approximately 50° C. for three months. At the end of that time the

films had not lost any weight. After one week, and again after three months, the air over the film was bubbled through a standard silver nitrate solution by drawing a current of air through the desiccator. A precipitate of silver cyanide was not formed in the silver nitrate solution.

HYDROCYANIC ACID

Experiments were performed to ascertain if hydrocyanic acid is evolved when nitrocellulose and cellulose acetate films are decomposed in a limited supply of oxygen, and if the amount formed varies with the amount of available air. Combustions were, therefore, made in a vacuum and at atmospheric pressure. Experiments were performed on films with and without the gelatin coating.

Combustions were made in a two-liter, round-bottom flask fitted with two stopcocks (Fig. 1), one leading to a suction pump and the other connecting with a gallon bottle, which was used to collect the gas for analysis. A manometer was placed between the round-bottom flask and the gallon bottle. Heat was applied to the nitrocellulose film with a Bunsen burner until fumes arose from the film, after which the burner was removed and the flameless combustion proceeded without external aid. As cellulose acetate films can be decomposed only by keeping them at a high temperature, the flask was heated with an electric hot plate. This was done so that the same amount of heat could be applied in all experiments and comparable results obtained. After the combustion, the system was allowed to cool until the pressure exerted by the gas remained constant. The manometer was then read, and the stop-cock shutting off the gallon bottle from the rest of the apparatus was closed. The gas was bubbled through two test tubes, each containing 10 c.c. of standard silver nitrate solution acidified with nitric acid. A 0.1 normal solution was used in the experiments in which a large amount of hydrocyanic acid was found, and a 0.05 normal solution in those in which

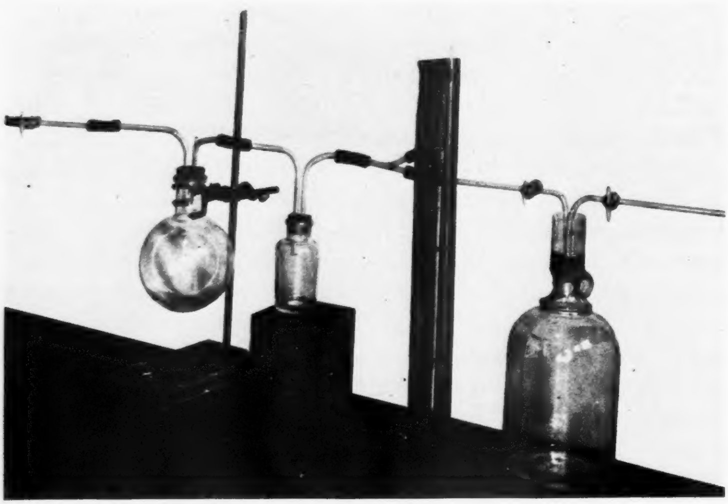


Fig. 1. Apparatus used for the combustion of film.

smaller amounts were obtained. Hydrocyanic acid reacts quantitatively with silver nitrate to form a white precipitate of silver cyanide (12). After all of the gas had bubbled through the silver nitrate solution, the latter was titrated with a standardized solution of potassium sulphocyanate, ferric ammonium sulphate being used as an indicator. The amount of hydrocyanic acid present in the gas could then be calculated from the quantity of precipitated silver cyanide obtained.

In former experiments (13) the gas was caused to bubble through the silver nitrate solution by allowing kerosene to drip into the gallon bottle, thus displacing the gas and forcing it through the solution. The kerosene used had been thoroughly shaken with concentrated sulphuric acid until the latter no longer appeared yellow after standing in contact with the kerosene for five minutes. This was done to remove the unsaturated hydrocarbons, as it was believed that, in their absence, hydrocyanic acid would not be taken up by the kerosene. After a number of combustions had been made, two blank determinations were made with the kerosene by allowing it to displace air, instead of gas, from the gallon bottle. A negligible amount of silver cyanide was formed in the silver nitrate solution. After the kerosene had been used for some time longer, another blank determination was made. This time an appreciable amount of precipitate was obtained. It was, therefore, thought advisable to check the kerosene by using some other method of bubbling the gas through the silver nitrate solution. This was done by drawing a current of air through the gallon bottle with a suction pump. In another experiment, nitrogen was admitted into the gallon bottle containing the gas until atmospheric pressure was obtained. The contents of the bottle were then removed by suction. Much larger amounts of silver cyanide were obtained in these experiments than in corresponding determinations in which kerosene was used. It was concluded that a large percentage of the hydrocyanic acid was taken up by the kerosene, and that the use of the latter would have to be abandoned. In all subsequent experiments the gas was drawn by evacuation from the gallon bottle through the silver nitrate solution. The pressure of the small amount of residual gas, which could not be removed by suction, was calculated from the manometric reading, and the amount of silver cyanide precipitate, which would have been formed from the entire volume of gas, could thus be calculated.

A qualitative test for the identification of a cyanide was made on the precipitates formed in the silver nitrate solution. The test used depends on the formation of a blood-red color due to ferricsulphocyanate. The test is performed as follows: a drop of yellow ammonium sulphide is added to a small amount of precipitate and evaporated to dryness. A drop of water is then added, followed by one of ferric chloride. In the presence of silver cyanide a blood-red color is obtained. The test was positive for all precipitates.

In the combustion of the nitrocellulose film in a vacuum, the following procedure was used: 12 gm. of film, cut into pieces about two inches square and made into a bundle, were placed in the two-liter, round-bottom flask, and the apparatus was evacuated. It was impossible to remove all of the air. A residual pressure varying from 10.5 to 16.5 mm. remained. The flask was then heated with a Bunsen burner until fumes appeared, after which the flame was removed, and the flameless combustion proceeded without external aid. After the apparatus had cooled to room temperature, the manometer was read and the stop-cock shutting off the gallon bottle from the rest of the apparatus was closed. The latter was again evacuated and a second combustion made

using 12 gm. of film, the stop-cock to the gallon bottle being opened when fumes appeared. The violence of the combustion forced small pieces of carbonaceous material through the outlet from the flask. It necessitated placing a 250 c.c. bottle for a safety trap between the flask and the manometer to prevent this material from clogging the stop-cock to the gallon bottle. The gas from these determinations was bubbled through three test tubes, each containing 10 c.c. of 0.1 normal silver nitrate solution.

In experiments on nitrocellulose film without gelatin, it was necessary to use much smaller quantities of film, as the combustions were more violent. Gelatin has a depressing influence on the combustion of nitrocellulose. When combustions were made in a vacuum, the residue consisted of a few black shreds. Three combustions of 2 gm. each were made in these determinations. The gas was drawn through two test tubes, each containing 10 c.c. of 0.05 normal silver nitrate solution.

Nitrocellulose film with gelatin in the amount of 8 gm. was used in the combustions at atmospheric pressure. In one experiment in which 12 gm. of film were used, pressure was developed sufficient to blow the rubber stopper out of the two-liter flask. To remove the hydrocyanic acid from the gas, 20 c.c. of 0.1 normal silver nitrate solution were used.

Experiments at atmospheric pressure could not be performed on nitrocellulose film without gelatin, because of the violence of the decomposition. In two experiments, 1 gm. of film was burned in a five-liter, round-bottom flask. In one case, the stopper of the flask was blown out, and, in the other, the outlet tubes from the five-liter flask and the 250 c.c. bottle were shattered. The film burned with a flame. The decomposition must have been complete, as there was no residue in the flask.

The procedure followed with acetate film was practically the same in all cases. Film, 12 gm., was cut into pieces and loosely placed in the bottom of the flask. Heat was applied with the hot plate for 13 minutes in the combustions made in a vacuum, and 11 minutes in those made at atmospheric pressure. One three-minute heating period was followed by either four or five two-minute heating periods. The flask was allowed to cool for five minutes between the heating periods, otherwise, in the case of the combustions at atmospheric pressure, considerable pressure would have developed due to the gas being at a high temperature. In all of the experiments with acetate film, the gas was bubbled through two test tubes, each containing 10 c.c. of 0.05 normal silver nitrate solution.

When a combustion was made with the cellulose acetate film, a black precipitate formed in the silver nitrate solution. Two more determinations were made, in both of which brown precipitates were obtained. All of these precipitates gave a positive reaction for a cyanide with the ferricsulphocyanate test. As a white precipitate was obtained from a combustion of cellulose acetate film without the gelatin coating, it was thought that the black and brown precipitates might be caused by some reducing agent from the gelatin reducing the silver nitrate solution. Reducing substances in solutions containing hydrocyanic acid can be titrated with 0.1 normal potassium permanganate solution without loss of hydrocyanic acid (14). It was thought, therefore, that by placing a tube filled with potassium permanganate crystals between the gallon bottle and the tubes containing the silver nitrate solution, any reducing substances which might be present in the gas would be removed. This was done in all subsequent experiments with coated cellulose acetate film. The precipitates formed had only a light yellow tinge.

In all experiments, the apparatus was en-

closed with wire screening for .protection. This was necessary even in the experiments with acetate film. In one determination at atmospheric pressure on cellulose acetate film, without the gelatin coating, the stopper of the two-liter flask was blown out and the fumes burned with flame in the flask. The ignition was probably caused by the hot gas, which undoubtedly had a high carbon monoxide content, coming into contact with the air.

The results of the experiments performed, given in the following tables, are calculated on the basis of 760 mm. pressure and 0° C. The percentages of hydrocyanic acid have been calculated on the actual volume of gas obtained. They do not include any air or nitrogen that was present before the combustion was made. All experiments were made on exposed film.

TABLE I.—EXPERIMENTS ON NITROCELLULOSE X-RAY FILM WITH THE GELATIN COATING, COMBUSTION TAKING PLACE IN A VACUUM

Residual Air Pressure	Grams Film Used	C.C. Gas per Gram Film	C.C. Gas in Gallon Bottle	C.C. HCN in Gas in Gallon Bottle	Percentage of HCN
(1) 13.2 mm.	24	244	2,839	44.8	1.58
(2) 12.5 mm.	24	238	2,732	45.6	1.67
Average		241			1.63

TABLE II.—EXPERIMENTS ON NITROCELLULOSE X-RAY FILM WITHOUT THE GELATIN COATING, COMBUSTION TAKING PLACE IN A VACUUM

Residual Air Pressure	Grams Film Used	C.C. Gas per Gram Film	C.C. Gas in Gallon Bottle	C.C. HCN in Gas in Gallon Bottle	Percentage of HCN
(3)* 16.4 mm.	6	264	624	6.2	0.99
(4) 14.7 mm.	6	272	645	5.6	0.86
Average		268			0.93

*Nitrogen was admitted into the gallon bottle containing the gas before the gas was bubbled through the silver nitrate solution.

TABLE III.—EXPERIMENTS ON NITROCELLULOSE X-RAY FILM WITH GELATIN COATING, COMBUSTION TAKING PLACE AT ATMOSPHERIC PRESSURE

Grams Film Used	C.C. Gas per Gram Film	C.C. Gas in Gallon Bottle	C.C. HCN in Gas in Gallon Bottle	Percentage of HCN
(5) 8	165	790	9.7	1.23
(6) 8	168	808	9.1	1.13
Average	166.5			1.18

TABLE IV.—EXPERIMENTS ON CELLULOSE ACETATE X-RAY FILM WITH GELATIN COATING, COMBUSTION TAKING PLACE IN A VACUUM

Grams of Film	Residual Air Pressure	C.C. Gas per Gram of Film	C.C. Gas in Gallon Bottle	C.C. HCN in Gas in Gallon Bottle	Percentage of HCN
(7) 12	10.5 mm.	55	396	3.6	0.9
(8) 12	11.5 mm.	57.6	415	3.4	0.82
Average		56.3			0.86

TABLE V.—EXPERIMENTS ON CELLULOSE ACETATE X-RAY FILM WITHOUT GELATIN COATING, COMBUSTION TAKING PLACE IN A VACUUM

Grams of Film	Residual Air Pressure	C.C. Gas per Gram of Film	C.C. Gas in Gallon Bottle	C.C. HCN in Gas in Gallon Bottle	Percentage of HCN
(9) 12	12.5	71	515	1.24	0.24
(10) 12	11.5	65.6	471	1.4	0.3
Average		68.3			0.27

TABLE VI.—EXPERIMENTS ON CELLULOSE ACETATE X-RAY FILM WITH GELATIN COATING, COMBUSTION TAKING PLACE AT ATMOSPHERIC PRESSURE

Grams of Film	C.C. Gas per Gram of Film	C.C. Gas in Gallon Bottle	C.C. HCN in Gas in Gallon Bottle	Percentage of HCN
(11) 12	44	318	1.28	0.4
(12) 12	49.4	355	1.14	0.32
Average	46.7			0.36

TABLE VII.—EXPERIMENTS ON CELLULOSE ACETATE X-RAY FILM WITHOUT GELATIN COATING, COMBUSTION TAKING PLACE AT ATMOSPHERIC PRESSURE

Grams of Film	C.C. Gas per Gram of Film	C.C. Gas in Gallon Bottle	C.C. HCN in Gas in Gallon Bottle	Percentage of HCN
(13) 12	51	370	0.45	0.12
(14) 12	57	409	0.41	0.1
Average	54			0.11

The difference between the results obtained in a vacuum and at atmospheric pressure was assumed to be due to the difference in the amount of oxygen present. However, it was thought advisable to determine whether or not the difference in pressure had any influence on the results. Experiments were, therefore, performed in an atmosphere of nitrogen. That is, the apparatus was evacuated and nitrogen, evolved by heating sodium nitrite and ammonium chloride, was admitted until the pressure it exerted was about half of an atmosphere. The results of these determinations are given in the following table:

TABLE VIII.—EXPERIMENTS ON NITROCELLULOSE X-RAY FILM WITH GELATIN COATING, COMBUSTION TAKING PLACE IN AN ATMOSPHERE OF NITROGEN

Grams of Film	Residual Air Pressure	Pressure of Nitrogen	C.C. Gas per Gram of Film	C.C. Gas in Gallon Bottle	C.C. HCN in Gas in Gallon Bottle	Percentage of HCN
(15) 12	13	325	245	1,766	23.7	1.34
(16) 12	14.7	347	234	1,688	27.2	1.61
(17) 12	13	349	243	1,753	26.9	1.53
Average			241			1.49

The results of Experiments No. 16 and No. 17, given in Table VIII, are in very close agreement with those obtained on nitrocellulose film with gelatin coating when the combustion was made in a vacuum. Even when the results of Experiment No. 15 are included, the average of the three determinations shows that any influence which the pressure may have on the amount of hydrocyanic acid formed is very small. It is believed that evacuation is a satisfactory method for limiting the amount of air for combustion.

SUMMARY

1. As 0.3 per cent is rapidly fatal, toxic concentrations of hydrocyanic acid were obtained in all of the experiments performed, except those on cellulose acetate film without the gelatin coating.

2. The results of the determinations made in a vacuum (and of those in an atmosphere of nitrogen) are very appreciably higher than those in which the air supply was limited to the amount of air enclosed in the apparatus. It can, therefore, be concluded that the amount of hydrocyanic acid formed decreases as the amount of available air increases, and that, if the films were burned in an excess of air, hydrocyanic acid would probably be absent entirely. This point has been established by other investigators (5), who state that hydrocyanic acid is not present in the gas from either nitrocellulose or cellulose acetate films when they are burned in an excess of air.

3. Hydrocyanic acid is apparently formed both from the gelatin coating and from the base of the film. The ratio of the amount of hydrocyanic acid formed from the gelatin to that formed from the film base is greater in acetate films than in nitrate films. These results would be expected from a theoretic consideration of the composition of the bases of the nitrate and acetate films. The nitrate base obviously contains a large amount of nitrogen, whereas the acetate base presumably does not contain any, and it would be expected that hydrocyanic acid would not be formed from the latter. Ex-

periments were not done to determine the source of the nitrogen which was necessary to form the hydrocyanic acid from the cellulose acetate base. Olsen, Brunjes, and Sabetta (5), however, found 0.34 per cent of nitrogen in an acetate film without the gelatin coating.

4. Although a large percentage of the hydrocyanic acid comes from the coating of both the nitrocellulose and cellulose acetate films, the gelatin probably reduces the fire hazard, as it appears to have a depressing influence on film combustion. There was a larger amount of residue from both types of film when the combustions were made on films with the gelatin coating. The amount of gas obtained, however, was larger when the combustions were made without the coating. The depressing influence of the gelatin appeared to be greater in nitrate film than in acetate. A considerable amount of carbonaceous residue and a small amount of condensate were obtained from the nitrate film with the gelatin coating. The removal of the gelatin resulted in a more complete type of combustion, as the residue consisted of only a few black shreds. Moreover, the nitrate film without gelatin burned with a flame when decomposed at atmospheric pressure. A flameless type of combustion was always obtained from films with the gelatin coating.

5. In order to decompose cellulose acetate film, it was necessary to keep it at a high temperature. Despite the high temperature, a very incomplete type of combustion resulted. The volume of gas obtained was small compared to that from the nitrate film, and a large amount of residue remained. While the films were being heated, they appeared to melt, forming a boiling liquid, which solidified into a very hard residue when the heat was removed. The acetate film without gelatin appeared to liquefy more completely when hot than the acetate film with the gelatin coating. A larger amount of gas and a smaller amount of residue were obtained from the former.

6. Although fatal concentrations of hydrocyanic acid were obtained in these experiments, it does not necessarily follow that hydrocyanic acid would be liberated in toxic quantities from much larger amounts of film. It is impossible to duplicate in a laboratory the conditions which exist when thousands of pounds of film decompose. However, it is reasonable to suppose that the air supply would be limited, and, in that case, that hydrocyanic acid would be formed. Under such conditions, carbon monoxide and the oxides of nitrogen would also be liberated from nitrocellulose films and carbon monoxide from cellulose acetate films. The danger of poisoning from hydrocyanic acid would be less than from either carbon monoxide or the oxides of nitrogen, as hydrocyanic acid is evolved in much smaller amounts. Fatal concentrations of carbon monoxide and of the oxides of nitrogen would still be present if concentrated fumes were diluted with a quantity of air sufficient to decrease the amount of hydrocyanic acid to non-toxic concentrations. Hydrocyanic acid, however, undoubtedly contributes to the toxicity of the gases evolved when large amounts of X-ray films decompose.

A consideration of the results obtained in this investigation leads to the conclusion that cellulose acetate films are superior to nitrocellulose films, from a safety standpoint, for three reasons:

1. Cellulose acetate films are more stable than nitrocellulose films. The latter readily decompose at 150° C., while acetate films must be kept at a high temperature in order to obtain decomposition.

2. Much larger amounts of gases are evolved from the flameless combustion of nitrocellulose films than from cellulose acetate films. Decomposition of the former is much more complete in a limited air supply,

as nitrate films contain a large amount of oxygen compared to acetate films.

3. Hydrocyanic acid is liberated in smaller quantities from acetate films than from nitrocellulose films. The oxides of nitrogen are entirely absent from the gases liberated from acetate film. Carbon monoxide, as shown by other investigators, is the only toxic gas liberated in comparable quantities from both types of film.

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DISCUSSION

PAUL C. SEEL (Rochester, N. Y.): After reviewing Miss Ballard's paper, we feel that she is deserving of no little credit for the manner in which she has conducted her investigation and assembled data from various sources. There are several points, however, which perhaps should be commented upon, these being as follows:

Miss Ballard states: "Celluloid burns only when brought in contact with a flame." It is possible under certain conditions, if nitrocellulose products, such as celluloid sheets or nitrocellulose films, come in contact with heat, to start decomposition, the products of which act as a catalyst, increasing the rate of decomposition, which raises the temperature sufficiently to cause ignition.

Further, Miss Ballard states: "Cellulose acetate or safety films did not decompose under the conditions under which nitrocellulose film did." Whereas the term "decomposition" can be correctly used with reference to any chemical breakdown such as is produced by heat, we feel the use of this term in describing the disintegration of cellulose acetate film by heating is to be discouraged. Persons familiar with the breakdown of nitrocellulose products have come to use the term "decomposition" in describing the reaction which is exothermic after the material has once been brought to a sufficient temperature for only a short period of time. Cellulose acetate films, on the other hand, require a continuous application of heat at an elevated temperature in order to accomplish this breakdown.

Later on, she says that some samples of nitrate film decomposed after from 30 to 40 seconds of exposure to a source of temperature of 250° C. (namely, a bath of molten paraffin into which was plunged a test bath containing the sample of film tied on to a thermometer bulb) although the temperature of the thermometer was raised to only 65° or 70° centigrade. Miss Ballard made some determination purporting to show that these low readings were not due to lag of the mercury in the thermometer bulb. It may be pointed out, however, that, under the conditions, she was not reading the equilibrium values and that the temperature readings have little meaning if they are not equilibrium values. The film was actually exposed to a source of heat at a temperature of 250° centigrade. Not only radiation of this temperature was reaching the film, but also any gas molecules having kinetic energy much higher than the average recorded by the thermometer. In our experience the temperature to which the film is raised by an exposure to a source of radiant heat can be ascertained only by careful calorimetric experiments.

Miss Ballard describes the method which she has used for determining the hydrocyanic formed. The Eastman Kodak Company's Research Laboratory feels that the method which Miss Ballard used is not quite so accurate as the one which they employed (Fig. 1).

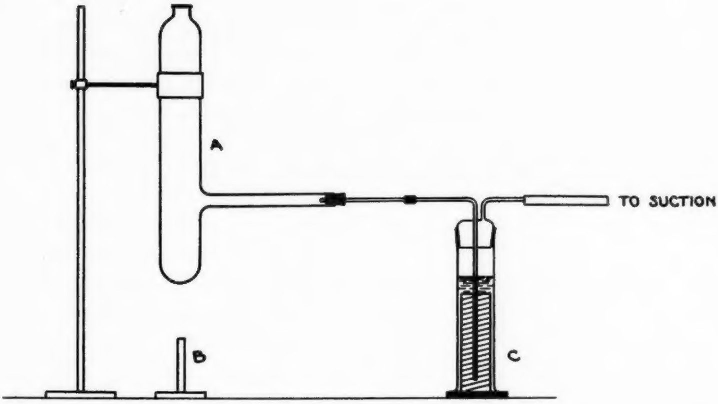


Fig. 1. The film was burned in the combustion chamber A, which is heated by the Bunsen burner B. The gaseous decomposition products were drawn off by suction, and passed through the Fisher gas washing bottle C, which contained a 10 per cent solution of sodium hydroxide. The downward draft produced by the suction prevents any of the gases from escaping at the top of the combustion chamber. The bottom part of the chamber, below the side-arm, becomes filled with the gaseous decomposition products, and the film is, therefore, decomposed in insufficient air to afford complete combustion.

The procedure for the quantitative estimation of the amount of hydrogen cyanide formed was based on the method published by Dundell and Bridgeman (*Jour. Ind. Eng. Chem.*, 1914, VI, 554). Other methods, such as those of Lubig and Volhard, were tried, but they were found to be unsatisfactory for various reasons. The method adopted depends upon the titration of the cyanide ion with nickel ammonium sulphate, using dimethylglyoxime as indicator. The nickel sulphate solution forms a soluble sodium nickel cyanide complex which removes the nickel ion from solution until an excess has been added. The presence of the excess is shown by the appearance of the pink color of nickel dimethylglyoxime, indicating the endpoint of the titration. The method, which was tested with known amounts of a standard potassium cyanide solution under the same conditions used in our experiments, was found to give trustworthy results.

For the experiments on the quantitative estimation of hydrogen cyanide, the following procedure was used. The sample to be tested was decomposed and the fumes absorbed, as previously described. The alkaline solution was acidified and distilled in a similar way, except that the distillate was absorbed in a dilute solution of ammonium hydroxide. The ammoniacal distillate was then titrated with a standard nickel ammonium sulphate solution as described above.

She gives the results of tests showing the amount of hydrocyanic acid gas liberated by the heating of cellulose acetate and nitrate films and film supports. Results of similar determinations made on or about August 14, 1929, in the Research Laboratories of the Eastman Kodak Company, are quite comparable with those obtained by Miss Ballard except in the case of the safety X-ray film support from which the emulsion layers have been removed. In this case our laboratories found no hydrocyanic acid to have been liberated whereas Miss Ballard shows 0.11 per cent. We are inclined to the belief that the difference in the results obtained by the two laboratories is due to the fact that it is very difficult to remove entirely the emulsion from

the film base due to the intimate bond between the base and the light-sensitive layers.

In the following table are shown the amounts of hydrocyanic acid gas which Miss Ballard found in the two types of film and the supports obtained from same by removing the emulsion compared to results obtained by the Eastman Kodak Research Laboratories on similar materials. There are also shown the amounts of hydrocyanic acid gas formed by heating wool yarn, glue-sized paper, and leather under conditions similar to those employed in heating the samples of film and film base:

	Miss Ballard's results Per cent	Eastman results Per cent
Nitrate X-ray film support	0.93*	0.93
Nitrate X-ray film	1.18	1.43
Safety X-ray film support	0.11	0.00
Safety X-ray film	0.36	0.50
Wool yarn	—	5.00
Glue-sized paper	—	0.66
Leather	—	3.00

*This result obtained by running test in vacuum.

When wool yarn, which is so commonly used for making rugs, carpeting, and draperies, is heated under destructive distillation conditions, it gives off approximately ten times the amount of hydrocyanic acid gas as is liberated from a like amount of safety X-ray film, and somewhat over three times the amount of hydrocyanic acid gas that is given off from nitrate X-ray films. A much higher percentage of hydrocyanic acid is given off from leather, or even from certain types of glue-sized papers, than from films. Of course, there is no question in anyone's mind as to any hazard existing from the slow burning of any one of these three materials.

The results as stated in Miss Ballard's paper agree in the main with the large amount of data which are available and are well known to persons who use the two types of X-ray film. There is only one other question which should be raised in connection with Miss Ballard's results: that is, while there may be sufficient quantities of hydrocyanic acid gas liberated from the destructive distillation of safety X-ray film to produce lethal dosages when the decomposition gases are not diluted with air, it is highly improbable that such results would be obtained when large quantities of X-ray films were slowly burned, for the hydrocyanic acid gas formed would undoubtedly be diluted either with other gases liberated from the film or with the surrounding air so that the amounts present would be considerably below the lethal amounts as described, *viz.*, 0.3 per cent.

In conclusion we want to state that one of the most important differences between nitrate and safety X-ray films is the fact that, if the nitrate film is heated and decomposition started, the reaction continues until the film is entirely consumed. With safety film, the breakdown can be effected only by continuously applying an external source of heat at a relatively high temperature, and if the source of heat is withdrawn, no further breakdown occurs.

Dr. H. B. Podlasky (Milwaukee, Wis.): Practically speaking, we have heard a great many comments on whether, in our everyday work, we should use safety film or nitrocellulose film. I care very little for absolute figures in medicine because you have seen how different laboratories, different physicists, will put the period at different places and the zeros in different places. What you want to do, perhaps, is to draw general conclusions.

The experiments of Eastman, with their wonderful facilities, absolutely show, I think, that Miss Ballard's work in the main is corroborated. The problem as to whether hydrocyanic acid, when liberated from the destruction of X-ray films, is actually the only cause of death, either immediate or remote, is not quite so important as the probability that hydrocyanic acid has been found under conditions which we know least about and which are enigmatic. Miss Ballard has shown that under certain conditions it is possible to get hydrocyanic acid; that it is a hazard which is to be considered in other fire occurrences I do not think is quite the consideration because we are not wool workers, we are not carpet workers, and we do not care very much about the presence of hydrocyanic acid except as it applies in our work with X-ray films.

One could carry this discussion on, I think, *ad libitum* and *ad nauseum* but it does remind one of this: the experimental data amassed

by well-known and authoritative workers have shown that the acetate film is the safest to use. Therefore, I think it is incumbent upon the radiologists of this country to use a product which guarantees a certain amount of safety to the public, in whose welfare we are interested.

I want to say in conclusion that, when a medical man tries to say a word or two commending a commercial product, he is immediately accused of having an ulterior motive. We have had that experience in Milwaukee, where we have tried to enforce a regulation making every radiologist use the acetate film. Despite this, I am going to be bold enough to say I do not care what you think or what thoughts you carry away, but I am convinced that we ought to use acetate film.

Miss Ballard (closing): The objections made by Mr. Seel to the experiments in which the nitrate film decomposed at 65-70° C. do not seem reasonable. The large glass tube, as well as the thermometer which was suspended in it, was at room temperature before it was plunged into the hot paraffin bath. As the small piece of film was fastened directly on the thermometer bulb, it received the same amount of heat as the thermometer. Although the heat was radiated from a hot paraffin bath at 250° C., the thermometer would still record the temperature of the air in the tube. Thermometers are used to record fluctuating as well as constant temperatures. The argument that some gas molecules have kinetic energy higher than the average recorded by the thermometer does not necessitate discarding the results of these experiments. The same argument would apply to the experiments in which the film decomposed at 150° C., and, in general, to any case in which a thermometer is used to record the temperature of a gas. The determination of the amount of heat present by means of a calorimeter, as Mr. Seel suggests, would not be superior to measuring the temperature of the air with a thermometer, because a calorimetric determination would also measure the average kinetic energy of the air molecules. It is believed that the decomposition temperature of from 65 to 70° C., obtained when a small piece of film was suddenly subjected to a great amount of heat, is approximately correct.

Mr. Seel believes that the difficulty of completely removing the gelatin coating was responsible for the hydrocyanic acid obtained from cellulose acetate film without gelatin. Although traces of gelatin probably remained on the film, the very small amount which was left could hardly be responsible for all of the hydrocyanic acid formed. The amount obtained from acetate film without gelatin is 30 per cent of the amount given off by the coated film. Only 70 per cent of the gelatin was removed, if the latter was the only source of hydrocyanic acid. The amount of gelatin left on the film was very much less than 30 per cent of the total amount of gelatin originally present.

Mr. Seel states that the hydrocyanic acid formed from large amounts of safety film would probably be diluted with other gases from the film. This dilution, however, is included in the concentrations of hydrocyanic acid found, as the percentage of hydrocyanic acid was calculated from the entire amount of gas obtained.

THE ANNUAL MEETING

In spite of the financial depression and the long distance many of our members had to travel to reach the Atlantic City meeting, the Eighteenth Annual Meeting was a great success. Several hundred members represented all parts of the United States and Canada; in fact, the registration surpassed in number the fondest expectation of the officers of the Society.

The technical exhibitors were well represented and, as usual, showed the latest achievements in American manufacture of X-ray and radium apparatus. All of their exhibits were not only interesting but instructive, as evidenced by the large attendance by the members of the Society.

The scientific program was of a high order, and the efficient manner in which the Presi-

(Continued on Page 46)

ABSORPTION CURVES AND SPECTRA OF X-RAY BEAMS[1]

By A. MUTSCHELLER, Ph.D., New York

DURING the Second International Congress of Radiology, in 1928, the committee elected to use, as a measure for radiation quality, an absorption curve in a known metal. However, during the Third International Congress, in 1931, the committee elected to rely upon the half value filter thickness as a measure for the radiation quality. While the first step was certainly commendable, the second is not of a character that indicates, from the theoretical point of view, that it has been made with good judgment.

The striking contradiction brought out in these decisions makes clear that either there is a lack of information of the exact meaning of the characteristics of an absorption curve, or that some of the properties of the radiation, as represented by the absorption curve, are generally overlooked. In some instances, the theoretical requirements for absorption curves seem to be fulfilled, but in others there seems to be disagreement with the theory as it is now formulated. This variance demands a more definite and rigorous interpretation of the characteristics of absorption curves.

Moreover, there are several frequently used tests for measuring and defining radiation quality which, fundamentally, are only different ways of interpreting absorption curves. If spectral measurements are excluded because they are too complicated for practical clinical purposes, then there is but the absorption curve that can be used for a dependable definition of radiation quality. From it, three distinct measures can be derived to define the quality of the radiation, really three different methods of interpreting the absorption curve.

1. The half value layer method, which is represented by the point on the absorption curve corresponding to a radiation decrease to one-half its original intensity.

Mathematically, it is equal to determining the slope of a secant of the absorption curve. It is obvious that this measure usually does not represent the actual composition of the beam as it passes through the filter.

2. The effective wave length, which is obtained from measuring the intensity before and after a known filter is introduced.

This measure also represents the slope of a secant, quite similar to that obtained with the half value layer method. Perhaps the results are a little more reliable, if the effective wave length measurement is made with the actual working filter used and the measuring filter is added to it, but the value obtained still depends upon the metallic measuring filter. Of course, a different value is obtained for this effective wave length for each and every metal used as a measuring filter.

3. The average wave length, which is a measure of a tangent to the absorption curve at the point which represents the thickness of the working filter.

As the author has pointed out (1, 2, 3, 4), this method is fundamentally the only dependable one for the correct definition of radiation quality. The measure of the average wave length is independent of the metal employed and only radiations which have absolutely identical spectra can possibly give the

[1]Read before the Radiological Society of North America, at the Seventeenth Annual Meeting, at St. Louis, Nov. 30–Dec. 4, 1931.

same average wave length with the same given filter thickness.

Inasmuch as the absorption curve appears to be the fundamental basis upon which modern methods of measuring radiation quality are established, it would appear desirable to investigate the physical meaning of the nature and character of absorption curves. Experimentally, it has been found that, in some instances, the semilogarithmic absorption curve becomes a straight line, and in other instances it remains curved. While making a large number of absorption curves under the most highly varied conditions, certain regularities have appeared, which are discussed and investigated.

THEORY

X-ray Spectrum.—When measuring the intensity of the different wave lengths of a radiation beam and plotting the wave lengths as abscissæ with the corresponding intensities as ordinates, we obtain a curve of an intensity wave length spectrum. A corresponding frequency spectrum, or an absorption coefficient spectrum is obtained if the proper transformations are made. The three spectra differ markedly in form and shape, but the areas under each of the three curves are equal and each area represents the total energy of the radiation (5). It can, therefore, be assumed that the area of any wave length band can be taken as a measure of the intensity of that band, compared with the intensity of another band of a different wave length in the same spectrum. Of course, if these wave length bands are located far apart on the wave length scale, then such a comparison could not be made, except after adequately correcting for the various factors that cause a deviation of the measured spectrum from the true spectrum. However, if the two areas are located close together and far to the short wave length end, then the measured ratio can be assumed to be reasonably close to that existing in the true spectrum.

If the radiation is filtered, for instance with regularly increasing filter thicknesses, as is done when an absorption curve is made, then the two bands decrease in intensity, each in accord with its absorption coefficient. Hence, the intensities of the two bands represent two points of an absorption curve.

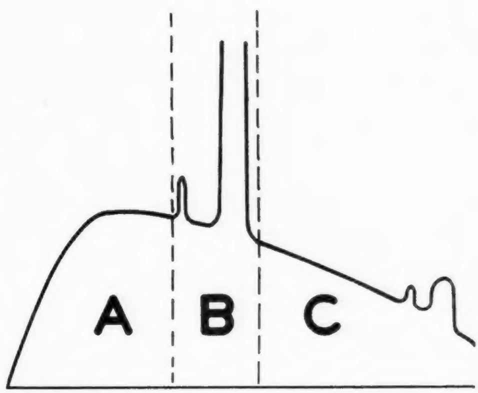
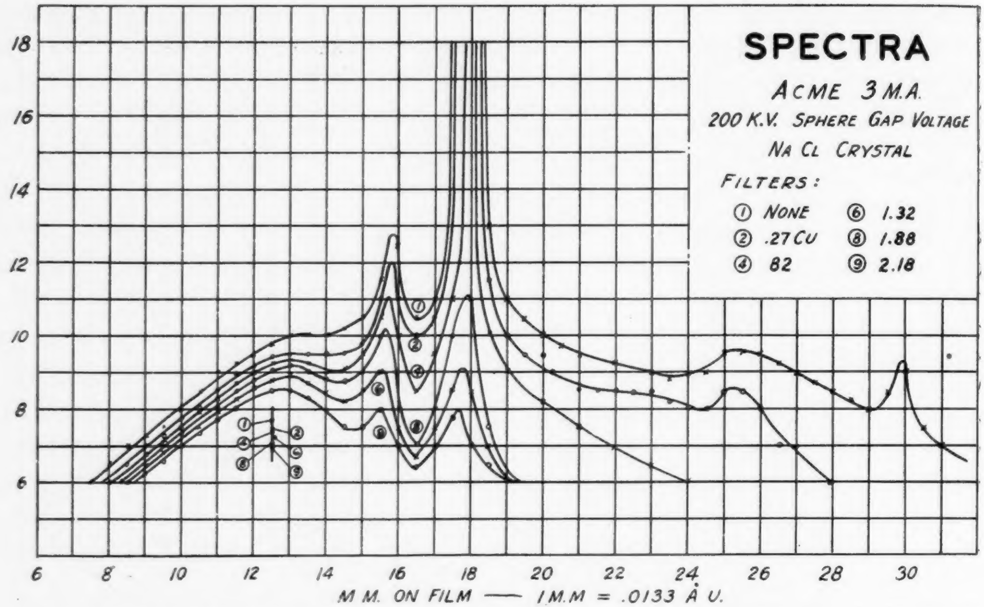


Fig. 1. A convenient way of dividing an X-ray spectrum into three zones.

Therefore, in a spectrum of a radiation above the characteristic voltage of the anode metal, three wave length zones can be outlined, each of which appears characteristically in different absorption curves. The band from the minimum wave length to the beta first order K line shall be designated as area A (Fig. 1); the band from the beta to and including the alpha K lines shall be designated as area B, and the remaining longer wave length portion of the spectrum as area C.

Absorption Curve.—Quite a different kind of curve is obtained if the intensity of the X-ray beam is measured each time after an additional thickness of metal has been placed in the beam. If these measured results are plotted as ordinates on a logarithmic scale



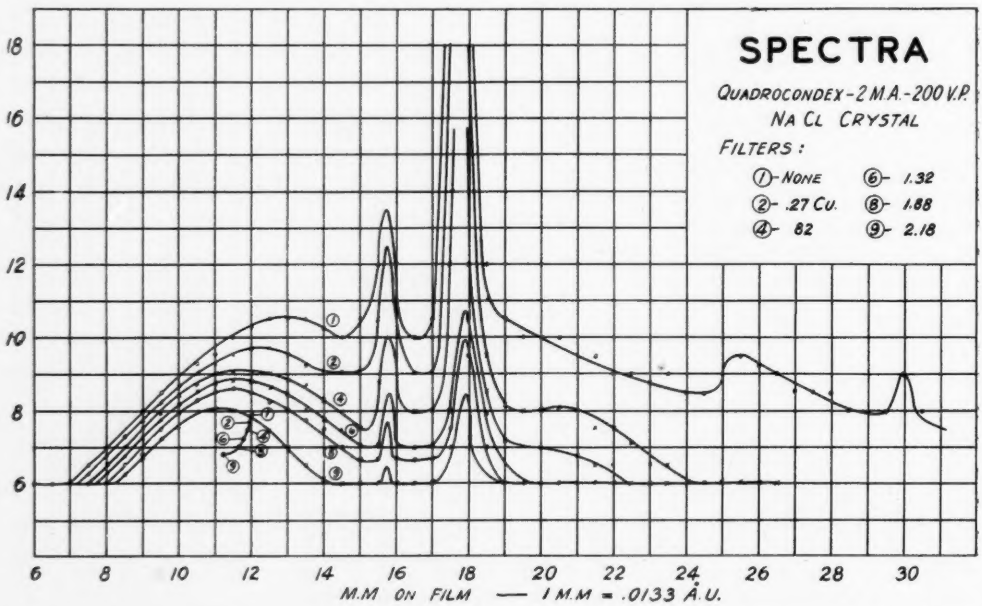


Fig. 2 *(above)*. X-ray spectra of Wo radiation with 200 K.V. of a mechanical rectifier through various filter thicknesses.

Fig. 3 *(below)*. X-ray spectra of Wo radiation with 200 K.V. uniform voltage through various filter thicknesses.

and the thickness of the metal as linear abscissæ, then we obtain a semilogarithmic absorption curve.

When the filters are thin, the curve, which is usually concave upward quite strongly at the start, gradually decreases in curvature.

When the filter thickness is increased, the curve gradually becomes more and more straightened out at the rate at which the radiation on the long wave length side of the characteristic lines has been filtered off. In some instances, it is found that the curve becomes an absolutely straight line; in other instances, it remains slightly bent. This seems to depend on the type of current or on the type of generating apparatus used for the production of the high voltage current and will be further discussed later on.

Until recently, the principal value of the absorption curve lay in the information that could be derived from it with regard to the effects of filters. Thus it was assumed that, if the absorption curve were straight, then nothing could be gained by increasing the filter thickness. Recently, however, some doubt has been expressed, based on the clinical evidence that a still different effect could be obtained with heavier filters.

Then, of course, there is the slope of the absorption curve which has always been considered as indicating the penetrating qualities of that radiation (5). With the aid of several known and experimentally proven relations, it was feasible to derive equations giving the radiation qualities in terms of half value layer thickness, effective wave length, and average wave length (5).

Due to the great importance of the absorption curve in measuring the quality of white X-ray beams, it is necessary to make a careful comparison between the meaning of the various indices of the spectrum and the absorption curve.

EXPERIMENTS

The experimental work has for its purpose the demonstration of the differences between the spectrum obtained with an X-ray tube energized with pulsating current, for instance, from a mechanical rectifier, and that obtained from an X-ray tube energized with uniform or constant voltage current. These spectra are to be compared with absorption curves and, if possible, the differences in the characteristics of the absorption curves above referred to are to be accounted for.

Apparatus *"A"* is a uniform voltage condenser type apparatus, with capacities of at least 0.1 M.F. The X-ray tube was operated with 2 ma., and 200 minimum wave length kilovolts. Apparatus *"B,"* a mechanical rectifier, was operated, using the same tube with 3 ma. and 200 K.V. measured with a sphere gap.

The X-ray tube has a specially fine focal spot of 5 mm. diameter. It is housed in a lead-lined drum provided with an opening through which the rays are directed through a similar opening in a wall upon the spectrograph located in another room. The diaphragms are of progressive sizes, approaching the spectrograph so that only direct rays coming from the active focal spot reach the NaCl crystal.

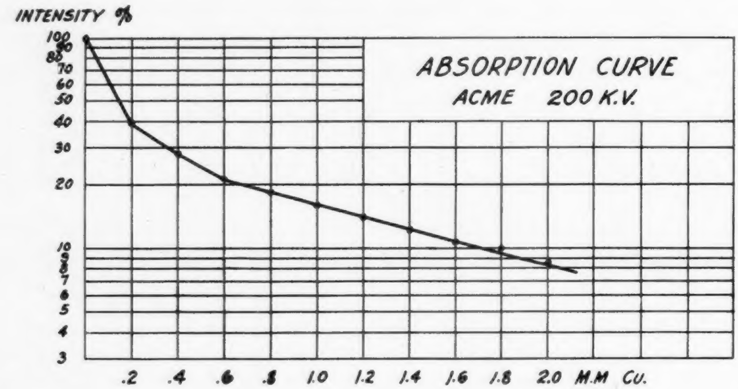
The spectrograph is of the rocking crystal type, especially constructed to insure absolute protection of the photographic films against stray rays. The filters were placed in the beam before it reached the spectrograph and the exposure times were so calculated, taking intensity data from the absorption curve, that all spectrograms received the same radiation dose. The spectra were all developed in one solution for the same length of time and they were then measured separately by a photometer. The direct results are plotted in Figures 2 and 3 (8). The lower scale is in millimeters along the film, each millimeter being equal to 0.0133 Ångström unit. The vertical scale, giving intensities, is in arbitrary units.

The absorption curves were then made with an instrument measuring only primary radiation. After the longer time has been divided by the shorter, the absorption data express, in percentages of the full unfiltered radiation, the intensities passing through

each of the filter thicknesses. The data obtained are directly plotted in Figures 4 and 5 on semilogarithmic cross-section paper. The horizontal line gives the absorber thicknesses in millimeters of copper; the vertical logarithmic line gives the intensity percentages in terms of the non-filtered radiation.

Characteristic in these spectra is the fact, previously reported, that the intensity maximum on the short wave length side of the characteristic lines is quite differently located on the wave length scale in the two groups of curves. The curves obtained with uniform voltage current are dome-shaped and have a distinct intensity maximum, separate and away from the characteristic lines. Those obtained with pulsating current, however, are of a more gradually ascending shape and do not have a maximum which is distinctly separate from the characteristic lines. Rather, they gradually fuse with the beta line of tungsten. Only the heavier filters gradually effect a separation of the short wave length area with an intensity maximum away from the beta line.

The characteristic lines produced with pulsating current are distinctly wider and heavier than those obtained with the uni-



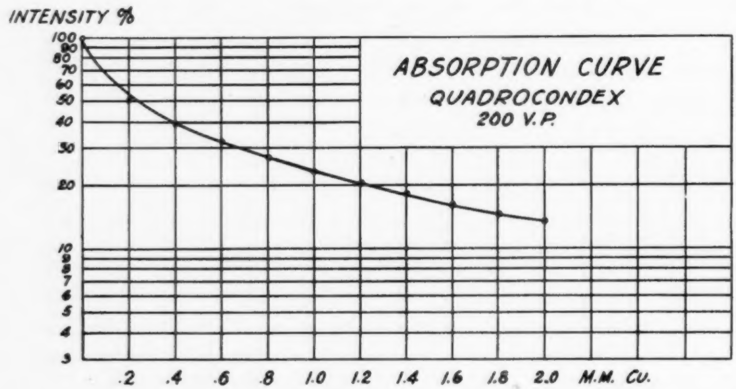


Fig. 4 *(above)*. Semilogarithmic absorption curve of Wo radiation with 200 K.V. of a mechanical rectifier.

Fig. 5 *(below)*. Semilogarithmic absorption curve of Wo radiation with 200 K.V. uniform voltage.

form voltage current. The reason for this may lie in the fact that the characteristic lines which are excited above 70 K.V., in a transient voltage curve, are excited for a much longer time than, for instance, the

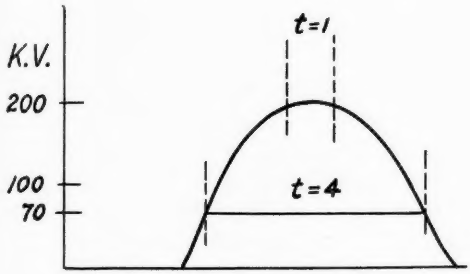


Fig. 6. A sine wave curve showing the relative exposure time for the characteristic *K* lines and the short wave length portion of the Wo spectrum.

short wave length end, which is excited only during the short time when maximum peak voltage exists (Fig. 6). This means that usually the characteristic lines are exposed four or five times as long as those of the short wave length part, and hence a proportional over-exposure of the characteristic lines is to be expected over the short wave length end of the spectrum. Of course, in the uniform voltage spectrum, all parts are exposed for equal lengths of time and all parts of the spectrum are probably more uniformly and more truthfully reproduced as the spectrum of tungsten. However, it is quite certain that, even in this case, there is considerable exaggeration of the actual width of the spectral lines, due to over-radiation.

The long wave length portion of the spectra in the two cases does not seem to offer anything of great importance except that in both cases approximately 0.75 mm. Cu is necessary as a filter for complete stoppage.

Of principal practical importance is the fact that, because it produces much greater radiation energies in the characteristic line zone, than does the X-ray tube energized with uniform potential, the pulsating current produces proportionally smaller amounts of radiation energy on the short wave length portion of the spectrum.

The spectra were then divided into three vertical areas, as previously outlined, the dividing lines being at the 15- and the 19-mm. vertical lines (Figs. 2 and 3). The geometric center of gravity of each of these areas was then determined. The spots marked 1, 2, 4, 6, 8, and 9 are the respective centers of gravity of the areas under each of the like marked curves. It is characteristic that in the spectrum of pulsating current, the centers of gravity of the short wave length areas are perpendicularly superposed. In the spectra obtained with uniform voltage, the centers of gravity of the heavier filtered short wave length areas are shifted distinctly toward the short wave length end. In the pulsating current, however, filtering does not appreciably change the wave length of the short wave length area; therefore, the average wave length of the radiation should remain unchanged by filtration. In uniform voltage rays, the average wave length changes, becoming shorter with every added filter thickness.

It is quite obvious that the center of gravity of the characteristic lines remains unchanged and, therefore, we can draw the conclusion that, with pulsating voltage, the average value of the wave lengths, *i.e.*, of the characteristic portion and of the short wave length portion, remains constant when the thickness of the filter is increased. With uniform voltage, however, the average value of these two wave lengths changes toward the short wave length end as the filter thickness is increased. This condition is then related to the fact that the absorption curve (Fig. 4) obtained with pulsating current shows straight line characteristics from a filter of 1 mm. of copper on. The absorption curve made with uniform

voltage radiation (Fig. 5), however, shows a uniform slight bend, especially in the part corresponding to the thicker copper filters.[2]

METHODS

The term "average wave length" was proposed by the writer in 1924 (1). At that time, the experimental work was performed with mechanical rectifiers which were always found to give straight line semilogarithmic absorption curves. The meaning of the term "average wave length" was, therefore, studied only along the straight line part of the absorption curve and it was then defined as "the wave length of a homogeneous radiation that is equivalent and absorbed to the same degree as the radiation tested" (1). A mathematical definition was also given, and, translated, it is: "The average wave length of a radiation is the wave length of an equivalent homogeneous radiation whose absorption is equal to that of the radiation tested" (2). It should, therefore, be quite clear in cases in which the absorption curve and the tangent to it are falling together, that it was proven experimentally in 1924 that the depth doses are proportional to the average wave length and, hence, that this term is a complete description of the radiation quality.

Later, however, when further studies were made, the method of measuring the average wave length was extended and it was stated, "Not only that part of the curve which is shown as a straight line and in which the absorption coefficient is constant can be used, but also any other point along the plot, even where it is curved, can be taken to determine the average wave length" (4). The average wave length is, therefore, to be determined from the slope of a tangent to the absorption curve drawn at the point corresponding to the filter.

In discussing average and effective wave lengths, in a recent paper (6), Taylor concludes that absorption curves are always curved and that "the most logical expression of the 'effective wave length' is obtained when using the absorption coefficient given by the slope of the logarithmic absorption curve. This is called the true effective wave length." What Taylor calls "true effective wave length" is just the average wave length, for both are determined by exactly the same process.

Wilsey (7) discusses the fixed filter, or effective wave length method, using Taylor's curves, and shows the inherent weaknesses of the method. However, he then comes to the conclusion that the absorption curve, which he defines as a curve giving log I or

$\log \frac{I}{I_0}$ plotted against the filter thickness,

has all the virtues which are to be expected of a satisfactory method of defining the quality; but the method which he refers to for determining it is also identical in every detail with the average wave length method, except that he proposes to record his measurements as the logarithm of the intensity ratio instead of calculating from this ratio the average wave length.

This leads us to the conclusion that the "average wave length" is an adequate measure of radiation quality even when the absorption curve is not a straight line, but no experimental proof of any kind is furnished.

A distinct contribution was made by Schwarzschild (5), who gives four distinct definitions of average wave length, all of which apply to the experimental results obtained from the slope of the absorption curve for varying thicknesses of absorbing material.

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[2]Despite the fact that the spectrograph received through each one of the filters the same total radiation dose, the areas under the spectra are considerably smaller with heavier filters than with the thinner ones or the non-filtered radiation. This is probably due to the dependence of the photographic effects upon wave length and the necessary crystal correction. Both these sources of error have not been accounted for in this work because we are here comparing spectra with approximately the same wave length distribution in the respective bands.

Consequently, we have to differentiate, before any discussion can go further, between four distinct methods of wave length measurement. These methods are illustrated with an absorption curve, for all really consist of special cases of interpreting absorption measurements. In Figure 7

1. The half value layer method is represented by "secant one-half value."
2. The effective wave length, or fixed filter method, is represented, for a filter of 0.75 mm. Cu, by "secant effective wave length."
3. The average wave length, when the absorption curve is not a straight line, is represented, for a filter of 0.75 mm. Cu, by "tangent average wave length."
4. The average wave length, when the absorption curve is a straight line, is represented by the same line as the "tangent average wave length."

There are, therefore, four distinct concepts, three of them giving different numerical values, as Schwarzschild has pointed out. Only the average wave length gives but one value which is not dependent upon the absorption material used to measure the radiation. Its value, of course, differs for various filters in accord with the fact that each filter changes the composition of the radiation in its own characteristic way. Hence the average wave length is the only measure that is characteristic of the radiation and not of the material used for its measurement, as was reported by the writer.

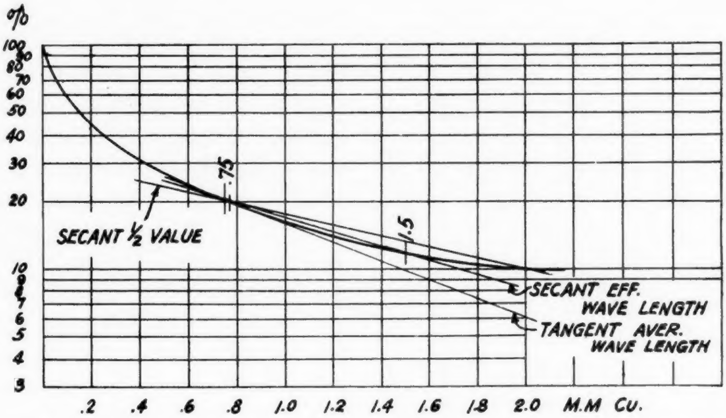

Fig. 7. Mathematical representation of the half value layer effective wave length, and average wave length as a description of radiation quality.

Regarding the interpretation or utilization of the absorption curve, it has been pointed out by the writer that neither the ratio $\frac{I_0}{I_x}$ nor $\log \frac{I_0}{I_x}$ has an interpretative or descriptive value, nor has it either any simple relation to biologic or energetic effects (3).

The following equations were derived for its interpretation:

$$\text{Log} \frac{I_0}{I_x} = 74.8\lambda^3 + 0.05 \text{ for 1 mm. Cu}$$

$$\text{Log} \frac{I_0}{I_x} = 9.1\lambda^3 + 0.085 \text{ for 5 mm. Al}$$

giving average wave length

$$\text{Log} \frac{I_0}{I_x} = \frac{74.8 \times (3 \times 10^{18})^3}{\nu^3} + 0.05$$

for 1 mm. Cu

$$\text{Log} \frac{I_0}{I_x} = \frac{9.1\ (3 \times 10^{18})^3}{\nu^3} + 0.085 \text{ for 5}$$

mm. Al, giving average frequency.

$$\text{Log } \frac{I_o}{I_x} = \frac{5.576 \times 10^{-22}}{W^3} + 0.05 \text{ for}$$
1 mm. Cu

$$\text{Log } \frac{I_o}{I_x} = \frac{6.9 \times 10^{-22}}{W^3} + 1.98 \text{ for } 5$$
mm. Al, giving average quantum energy (9).

Because all these equations are derived from experimentally proven relations, they give dependable results if they are not used beyond the critical absorption bands of the metals, and provided the absorption curve is straight and hence falling together with the tangent drawn to curve.

The most important point for discussion at this stage is whether or not the semi-logarithmic plot of absorption values against absorber thicknesses can possibly become a straight line. It is true that, on the basis of mathematical reasoning, when certain definite assumptions are made, the straight line would seem to be improbable. But it must not be forgotten that the assumptions made for the mathematical expressions are not in conformity with the actual spectrum of a composite X-ray beam.

So, for instance, we find that from an X-ray tube excited with pulsating current, when heavier filters are used, the semi-logarithmic absorption curve always is straight. The spectra then also show that the centers of gravity of the short wave length areas *(A)* do not shift and that the characteristic lines *(B)* are distinctly heavier in relation to the short wave length areas *(A)* than is found in the spectra obtained with uniform voltage.

It is, therefore, quite certain that the ratio of the two intensities of the short wave length area *(A)* against the intensities of the characteristic lines *(B)* is not the same in the two cases. If we keep in mind that the relative decrease of a radiation depends on its original intensity and its average absorption coefficient, it becomes clear that, in a band of great intensity and width, there is a greater change of intensity distribution after heavy filtration than in a band of relatively lower intensity. Hence, it would be likely that we should find the ratio of the intensities of areas *A* and *B* changing differently if these intensity ratios are unequal as in the two experimental cases.

But, in addition to this, the absorption coefficients of the filtered short wave length areas *(A)* gradually shift to smaller values, and thus the transmission ratio is made still more non-uniform. In such a case, the semi-logarithmic absorption curve must remain curved, for the resulting intensity ratio would change continually with increasing filter thicknesses.[3]

From the foregoing, therefore, we have to draw the conclusion that the straight line absorption curve is not only possible, but that it has a definite significance and that it can be definitely interpreted in indicating depth doses in copper or in other substances. In this case, all the expectations for the value of the average wave length are realized.

For, if the absorption curve is not a straight line, then the average wave length, for indicating depth doses, loses its significance because it is unable to indicate intensities through greater filter thicknesses or other desirable factors such as depth doses in water or tissues. In fact all the information that the average wave length conveys is what sort of radiation complex falls upon the surface of the skin and how it may affect the immediate surface layers. But because the absorption curve bends away from the tangent, it can say nothing about any depth dose or effects produced at the greater depths in the absorber. Therefore, the general conclusions on the value of the

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[3]In a private communication, Schwarzschild states that he derived an expression for the rate of change of the average absorption coefficient ($\bar{\mu}$) for two homogeneous beams. If r is the ratio of the energies in the two wave length bands, then the rate of change of the average absorption coefficients ($\bar{\mu}$) with increasing filter thickness is proportional to $\frac{r}{(r-1)^2}$.

slope of a tangent to an absorption curve are only conditionally justified, *i.e.*, in that case alone when the absorption curve is a straight line.

From this it follows that the bent absorption curve cannot be interpreted, with respect to radiation quality or depth doses, except by further treatment either mathematically, to account for the deviation of the absorption curve from the straight tangent, or by special filters, perhaps combinations of several metals through which straight line semilogarithmic absorption curves are obtained.

Then, in that case, the slope of a tangent, or the average wave length, has a definite meaning in that it definitely describes the radiation quality and the depth doses obtainable with it. But we should remember that partly filtered radiation beams, which are not filtered to have a constant absorption coefficient or a straight semilogarithmic absorption curve, are not of the kind about which any definite or systematic information regarding their actions in the depths of tissues is known, nor will the use of them be anything but empiric.

CONCLUSIONS

1. Pulsating high voltage current gives practically complete, straight, semilogarithmic absorption curves.
2. Uniform potential current gives bent, semilogarithmic absorption curves.
3. The reasons for the variation seem to lie in the different spectral distributions of the wave length intensities in the two cases.
4. Pulsating current produces relatively greater intensities in the characteristic line area, compared with the intensity of the radiation on the short wave length side of the characteristic lines, than uniform voltage current.
5. The intensity maximum of the short wave length portion, produced by uniform voltage, changes on the wave length scale with increased filter thickness.
6. The intensity maximum of the short wave length portion produced by pulsating voltage current does not change with change of filters on the wave length scale.
7. The "average wave length," or any other interpretation of the slope of a semilogarithmic absorption curve, has a direct meaning when applied to radiation quality or depth actions only if the semilogarithmic absorption curve is a straight line.
8. Suggestions are indicated of the treatment of bent absorption curves. Work in these directions is in progress.

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DISCUSSION

DR. LAURISTON TAYLOR (Washington, D. C.): The first point to which I wish to draw attention is the shape of the copper absorption curve, which is fundamental to Dr. Mutscheller's whole discussion.

Back in 1924 he stated that in the measurement of the "average wave length" you must use a portion of the curve which is straight. I have tried for a number of years to get a straight absorption curve by any means whatever that was fair, but I have been unable to do so.

We have used standard ionization chambers and thimble chambers; we have used ma-

chines of every make that is found in the market, and invariably the curve is non-rectilinear over any portion of its length, even in carrying the filtration up to 3 mm. of copper.

There is a possibility that the straight line which was shown in one of the slides might be attributed to uncorrected wall effect, or some such factor, in the thimble chamber with which the measurements were made. However, I understand that this has been taken into consideration. I might say that, when making measurements with thimble chambers, we do occasionally get points through which you might draw a straight line if you want to regard the points as being badly scattered.

To-day Dr. Mutscheller brought out the point that the absorption curves become straight only for mechanical rectifiers, stating that his early work was done with mechanical rectifiers; that to-day, working with constant potential machines, the absorption curves are curved throughout. I am a little bit confused by this because, as I say, I have been unable ever to obtain a straight line relationship and I cannot see, myself, why we should expect any very nice balancing of the radiation intensities in the line radiation and in the short wave length radiation which would bring about such a condition as that. It could be very nice if it worked out that way, but it does not very often do that.

The average wave length, as Dr. Mutscheller has described it, was originally limited to a portion of the absorption curve that was straight. That was later extended, I believe, without very much explanation, to portions of the curve that were not straight, namely, below the point at which so-called "homogeneity filtration" was reached. In a paper from Memorial Hospital and in one from the Bureau of Standards, in which these relationships were discussed, the slope of the absorption curve was referred to as the effective wave length. I believe the Bureau publication calls it "true wave length" to distinguish it from Duane's "finite" filter wave length.

Fundamentally, the average wave length, as Dr. Mutscheller is now using the term—namely, the slope of the tangent at any point of the absorption curve—is none other than the true effective wave length, which has been known for many years.

The statement is also made that average wave length, obtained as he does it, is independent of the particular filter material used for making the measurement. He also states that average wave length and effective wave length are identical when you deal with slope of the curve. We have made a great many measurements in which we have talked in terms of effective wave length, using copper, zinc, and aluminum for determining the average or effective wave length, and in no case have we ever obtained agreement between two metals.

For example, if you plot a semilogarithmic curve, say, for aluminum, that is the log of $\frac{I}{I_o}$ against increasing copper filtration, the slope of this curve as shown in Dr. Mutscheller's paper gives you the effective wave length as obtained from data on the absorption of X-rays in aluminum.

If you start, say, at a middle point and add copper filtration, you will obtain a second curve which drops below the first, and by the same method as above you can draw a tangent to this curve at the point, or approximately at the point, of intersection there. The curvature is not very great, so that you can get the tangent very accurately and from that tangent you get an effective wave length of the radiation corresponding to that point.

By a tangent method, exactly the same method in both cases, you can do the same thing, using zinc, and you will get three different values of the effective wave length—widely different values, too, except for certain accidental cases. If radiation is pretty well filtered to begin with, those methods are all going to be widely divergent.

Dr. Mutscheller has also stated that, when you use the average wave length, you are obtaining a measurement which is proportional to the depth dose of the radiation from which the average wave length is obtained. That is very true and that is a point which I want to strengthen, but there again it is not a thing which is limited to average wave length.

The semilogarithmic absorption relationship does not need to become straight in order to give a factor which is proportionate to the depth dose. If we have two semilogarithmic absorption curves, one at 140 K.V. and one at 200 K.V., we can match two portions of those curves—the 140 K.V. curve, say, above 0.7 mm. of copper and the 200 K.V. curve above 0.3 mm. of copper; we find that above those points the two curves can be made to coincide.

We also find that everything else about those radiations coincides to a fair degree, not exactly, but the depth dose relationships for the remaining radiations are very similar, which is what Dr. Mutscheller pointed out as being one of the main factors in favor of using the average wave length.

The principal point that I want to bring out is this: we have in this country now many different methods for measuring quality. We have six different brands of effective wave length, and we have a half value layer of aluminum and copper, and we have the average wave length. The unfortunate thing about it is that none of these quality measurements is in any simple way comparable.

As a result, Dr. A measures an effective wave length using 0.25 mm. Cu, and Dr. B measures average wave length, and Dr. C uses 0.5 mm. layer of aluminum. When they publish their results, you find they might as well give sphere gap and milliamperes (and guess at the distance between the sphere gap as far as obtaining any real benefit from the measurement is concerned).

The thing that seems to me to be of utmost importance is not to have so many methods for measuring quality. The average wave length is not fundamentally different from effective wave length, which has been known for a great many years. The half value layer is used almost entirely in Europe with the result that at the Congress in Paris it was decided to use only the half value layer method for international purposes. The sole reason for doing that was not because they thought the half value layer method really better than others, but simply to get rid of all the others and have only one method, however poor it may be, so that we may all talk in the same terms.

I do not wish to discourage constructive ideas, but I do think that in putting forth these ideas we should not confuse those which we already have, and I think that is what is taking place in the average wave length measurement.

Dr. Ernst A. Pohle (Madison, Wisconsin): Dr. Taylor has discussed in detail the physical points in this paper so that there are only a few words left for me to say from the standpoint of the radiologist.

We all would like very much to see one factor to express quality, one factor which is simple to determine. I have for some years advocated the effective wave length as proposed by Duane, for the sole reason that it takes only two readings with an ionization instrument and then the use of this author's chart.

However, I have also come to the conclusion, after comparing all the data which I have accumulated and classified for the past six years, that there is no single factor at present, much as we would like to have it, that can express quality with accuracy. I have come to the decision that the only thing to recommend at present is to plot a complete absorption curve and let this curve, as such, stand for the expression of quality. That means, of course, more work in determining it but it is, to my knowledge, the only accurate way of defining quality. From that curve, one may of course easily derive quality factors, such as the absorption coefficient, the true effective wave length, and the half value layer.

Dr. G. Failla (New York, N. Y.): I think Dr. Pohle has pointed out that it is difficult to express completely the quality of radiation. One factor alone is not sufficient, whether that factor be the effective wave length, or the average wave length, or the absorption coefficient, or the half value layer. It cannot be expressed by specifying only one of those factors.

For practical purposes, if it is a question of determining the depth dose from the knowledge of one of these factors, any one of them

will do that with fair accuracy. The reason is that in a depth dose determination one is dealing with absorption in a medium of low atomic weight, as water and tissues, which are essentially, or largely, water. In this case, it is not so much the absorption of radiation in the water as the scattering of the radiation by the water, which decreases the intensity as one goes down into the deeper layers, and the scattering does not vary much for different qualities of radiation within reasonable limits.

The depth dose does not change very much when the quality of radiation is changed to a considerable extent; therefore, any one of these factors can be used. One may be a little better than another, but they all will give results which are within the limits of practical requirements.

The principle of the instrument which Dr. Mutscheller has described is the same as that of the mecapion—a German instrument—the only difference being that, instead of using the ordinary vacuum tube, Dr. Mutscheller uses a "trigger" tube.

On the other hand, the instrument depends on an increase in voltage on the grid of this tube, and, therefore, its insulation and the insulation of the condenser, which is across the tube, will influence the calibration of the instrument. The method of measurement is one in which the characteristics of the tube and the characteristics of the condenser used for varying the sensitivity of the instrument will influence the reading.

This difficulty is overcome by incorporating a uranium standard which enables one to calibrate the instrument at any time. But, of course, this introduces an additional operation in the use of the instrument.

Dr. Roy Kegerreis (Chicago, Ill.): Dr. Mutscheller was the first one to suggest the average wave length as a criterion for measurement, so far as I know, and I think he should be complimented now, since others are taking up the ideas which he expounded earlier.

While a complete calibration should be made when a new machine is put in service, most calibrations are made merely to determine if a machine is performing as it did previously. In such a case, practically any method of calibration will be satisfactory if it is carefully done.

Dr. R. R. Newell (San Francisco): Will we be able to persuade therapists to use rays which will give a straight line absorption curve? Will they increase their filter to that point?

Dr. Mutscheller: It is not a question of increasing the filter to a greater thickness; it is a question of combining different metals, probably.

Dr. Newell: You said that a single figure would give a measure of the quality if the absorption curve is a straight line.

Dr. Mutscheller: Yes.

Dr. Newell: But if the therapists insist on using a thinner filter than that, then it cannot be specified with one figure.

Dr. Mutscheller: No. I might add that this one figure on the probable curve applies only to a very small thickness. As soon as you get filter down into the body tissues, conditions change—we do not know in what relation.

Dr. R. R. Newell (San Francisco, Calif.): I think that by the time six of us have said so, it will become rather well understood that no single measure—no single number—can give a measure of quality. If we wish a complete comparison of quality between two different radiations, we must have their complete spectrograms.

As clinicians, we are interested in the quality of X-rays for two purposes: one, to discover the distribution of energy in the tissues of the patient; and the other, to discover the quality which is acting on the cells, for it is still possible that different wave lengths give different biologic effects.

We are now talking about radiations which are produced at moderately high voltages and filtered through moderately heavy copper filters, those of 0.5 mm. or more. If we limit our discussion to such radiation, we will see

that the increase in hardness due to further filtration in the tissues is entirely negligible compared with the increasing softness of the average radiation in the tissue from the addition of scattered ray (Compton effect).

The consequence is that, when we apply a filtered ray of an average wave length of 0.15 to the surface of a woman's pelvis, we find the average wave length which penetrates into her uterus is not harder on account of the filtration of her body, but very much softer. It may be as soft as 0.2 average effective wave length by the time it gets into the middle of her pelvis.

Why be ultra-precise about the spectral composition of an X-ray beam when it will have that composition markedly altered in uncertain degree by the reaction of the patient upon it? I would be perfectly contented, for medical records, with the specification of wave length by any of these methods: (1) half absorption thickness in copper; or (2) half absorption thickness in aluminum; or (3) average wave length, which is the tangent of the absorption curve line; or (4) mean effective wave length.

Or I should be quite content with this restriction: that one stated he was using a half-wave, or a mechanically rectified machine, or a constant potential machine, and specified the voltage indicated by the sphere gap. I think any of those is sufficiently close for medical records—not for physical record, but for medical records; I think we are making a great deal of ado over a very small difference.

Dr. Mutscheller (closing): There are, of course, many things that I have not mentioned because the discussion would have become entirely too long. I believe that this omission is responsible for part of the trouble under which Dr. Taylor is laboring.

When I say "straight" absorption curve then we have to consider the lower end. The first, or upper, part of an absorption curve is always bent and according to conditions the bend diminishes until the curve finally approaches a straight line. For practical purposes, therefore, the bend becomes gradually less and less so that we can assume it to have approached a straight line.

I can take some of Dr. Taylor's curves and I am satisfied that they are straight lines within the zone within which I would use them. But there is one point that limits our discussion and that is, if you go to still heavier filters than 2 mm. Cu, then conditions may change. Then the characteristic lines begin to disappear from the spectrum and we have only the short wave length end of the spectrum left. From that point on, of necessity, the curve must bend again. Therefore, the straightness, or the straight characteristic, is one which is not complete but which is only approached as we continue filtering.

I am surprised that Dr. Taylor did get different numerical values when using various metals for determining the average wave length, but there must be an error involved, because this is necessarily so theoretically. In practice I am obtaining exactly the same numerical value for the average wave length irrespective of whether I use, for instance, aluminum or copper.

Of course, that means that the ratios of intensities must be interpreted by the relations which I derived and which are based absolutely on experimental facts. I say again I do not know why he does not get the same numerical values with the two metals. There must be an error of some kind.

Now if we come down to the practical side of this question, this point arises: that the half value layer method and the effective wave length method as described by Duane (he for the first time used the expression "effective wave length") are secants to an absorption curve and that is entirely different from what we call the average wave length, which is a tangent, an entirely different thing, and we have to keep them apart.

Of course, of these three quality designations only the average wave length gives one numerical value. With the others you can get any numerical value that you care to get, by simply using a different filter thickness or a different metal, and with each one of them you will get a different value.

Dr. Newell appears rather easily pleased, but I believe I have to state that these efforts are really the first step in an attempt to evolve finally a method which gives us under all circumstances one definite numerical value as a description of the radiation quality. At this time I am making the bold statement that one numerical value describes fully the radiation quality if the absorption curve is a straight line. I am in a position to prove that.

But at the moment when the absorption curve is bent, then we lose control over the situation. For that reason I am stressing the straight absorption curve because there are possibilities that we may be able to use such filter combinations as will ultimately give the straight absorption curves. Then we will have the situation clear; we will be able to calculate, and we will have made a distinct step in advance insofar as we can describe radiation by only one figure, and that will be the ultimate aim.

THE ANNUAL MEETING

(Continued from Page 31)

dent, Francis Carter Wood, M.D., conducted the meeting stamps him as one of the most capable presidents the Radiological Society of North America has ever had. The active participation of the President-elect, Byron H. Jackson, M.D., in the affairs of the Society at the meeting gives promise that he will make a most capable president for the coming year.

The scientific exhibits reached, as usual, a high standard. In order that our readers may appreciate the character of these exhibits and the research work which is being done in radiology, we believe we are warranted in mentioning those who participated in the Scientific Exhibit.

M. M. Pomeranz, M.D., Hospital for Joint Diseases, New York: "Early and Late Lesions of Bone and Joint Tuberculosis."

Eugene Freedman, M.D., Cleveland City Hospital: "Primary Tumors of the Lungs."

B. I. Golden, M.D., Davis Memorial Hospital, Elkins, W. Va.: "Visualization of Bilateral Psoas Abscess, with Demonstration of Pott's Disease."

Leon J. Menville, M.D., and J. A. Ané, M.D., Tulane University, New Orleans: "Visualization of the Lymphatic System."

J. Thompson Stevens, M.D., J. Thompson Stevens Clinic, and Montclair Community Hospital, Montclair, N. J.; St. Joseph's Hospital, Paterson, N. J.: "Some Results of Treatment of Accessible Malignancies with Electrothermic Surgery, Radium, and Roentgen Rays."

W. W. Watkins, M.D., Pathological Laboratory, Phoenix, Ariz.: "Lung Cavities: Various Methods of Treatment, under X-ray Control."

I. Seth Hirsch, M.D., New York: "Kimoroentgenography: Roentgen Study of Cardiac Movements."

Lewis G. Cole, M.D., Cole Collaborators, New York: "Pathology and Roentgenography of Gastric Ulcer."

Hans A. Jarre, M.D., Laboratories of R. H. Stevens, M.D., H. A. Jarre, M.D., and C. K. Hasley, M.D., and Grace Hospital, Detroit: "Pyeloperistalsis during Infection."

Francis Carter Wood, M.D., Institute of Cancer Research, New York: "Synthetic Cancer."

J. D. Camp, M.D., Mayo Foundation for Medical A. C. Furstenberg, M.D., Ann Arbor, Mich.: "Osseous Changes in Hyperparathyroidism."

Otto Glasser, Ph.D., Cleveland Clinic Foundation, Cleveland: "Scientific Forefathers of Wilhelm Conrad Roentgen."

S. W. Donaldson, M.D., C. B. Peirce, M.D., and A. C. Furstenberg, M.D., Ann Arbor, Mich.: "Osteomyelitis of Skull."

W. B. Coley, M.D., Memorial Hospital and Hospital for Ruptured and Crippled, New York: "Different Types of Bone Sarcoma."

J. S. Lewis, Jr., M.D., and E. C. Baker, M.D., Youngstown Hospital: "Urograms of Normal Pregnancies."

R. S. Bromer, M.D., Philadelphia: "I—Osteogenesis Imperfecta. II.—Case of Osteitis Fibrosa Cystica with Giant-cell Tumor Formation Associated with Parathyroid Disturbance."

G. E. Pfahler, M.D., and J. H. Vastine, M.D., Philadelphia: 'Technic for Radium Treatment of Cancer of Mouth, with Results."

The awards were made by a special committee who gave a great deal of time to study of the various exhibits before reaching a conclusion in regard to the merit of the various exhibitors.

First award Hans A. Jarre, M.D., Detroit: "Pyeloperistalsis during Infection."

Second award Leon J. Menville, M.D., and Joseph N. Ané, M.D., Tulane University, New Orleans: "Visualization of the Lymphatic System."

Third Award George E. Pfahler, M.D., and Jacob H. Vastine, M.D., Philadelphia: "Technic for Radium Treatment of Cancer of the Mouth, with Results."

Honorable Mention John D. Camp, M.D., Rochester, Minnesota: "Osseous Changes in Hyperparathyroidism."

Honorable Mention Lewis G. Cole, M.D., New York: "Pathology and Roentgenology of Gastric Ulcer."

The Society's Gold Medal was awarded to Leon J. Menville, M.D., of New Orleans, for the visualization of the lymphatic glands and his experimental studies on the alimentary tract of rachitic rats.

THE PATHOLOGY OF MONOMELIC FLOWING HYPEROSTOSIS OR MELORHEOSTOSIS[1]

By ERNEST KRAFT, M.D., New York City

At the annual session of the American Medical Association in June, 1931, the writer discussed a rare disease known as melorheostosis, or flowing hyperostosis, of a single extremity. This condition was first described by Léri and Joanny (9). Three years after, Lewin and McLeod (13) also reported an independent observation as an unclassified osteosclerosis. The fact that the American roentgen literature is lacking in discussion of the subject suggests that its publication might be of interest.[2]

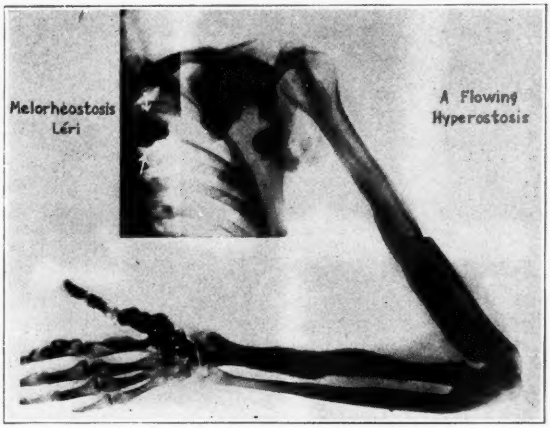

Fig. 1. Complete continuous hyperostotic flow from shoulder to phalanges. Ankylosis of first and second carpometacarpal joints. Bowing deformity of proximal ulna. Arrows point to hyperostosis of cartilaginous junction of first rib. Numerous heterotopic formations in axilla and below clavicle. The lesions have been slowly progressive for 19 years and seem to have developed from a circumscribed and interrupted flow. (Personal observation.)

An excellent review of the first seven cases[3] was published by Léri and Lièvre (10) in 1928. In another publication (8) I referred to a total of 16 cases. Two additional cases[4] were reported by Rokhlin (23) and Weil and Weismann-Netter (28).

Following my first presentation several roentgenologists of this continent told me of their own observations. Sussman (25) had seen a case being diagnosed as marble bone disease. At the clinic on bone sarcoma of Johns Hopkins University, two unpublished cases were demonstrated on Sept. 21, 1932.[4] The first case, shown by Major J. J. Moore, of the Walter Reed Hospital, was a man, aged 38 years, in whom a lower extremity was affected by a practically complete, continuous flow of hyperostosis extending from the hip to the foot. Radiographs taken in 1922 revealed eburnation of the femur. The other case, shown by Dr. B. M. Parmelee, Bridgeport, Conn., was a woman, aged 23 years, who had suffered from rheumatic pain of the right hip for five years. The symptoms increased in severity following a childbirth. The radiographic examination disclosed a complete continuous flow of hyperostosis extending from the right sacroiliac area to the phalanges. Dr. Sherwood Moore, of St. Louis, saw a case of melorheostosis in a middle-aged woman, who apparently had a circumscribed affection of a fibula. Another case was observed by Dr. Sante, of St. Louis, about ten years ago. Dr. Sante sent me his reproductions and permitted me to utilize his material. In his case, the hyperostosis was limited to the fourth right metacarpal and adjacent phalanx (Fig. 8). No other films were made,

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[1]Read by title before the Radiological Society of North America, at the Seventeenth Annual Meeting, at St. Louis, Nov. 30–Dec. 4, 1931.

[2]The writer is indebted to several authors for their reproductions, to Dr. I. S. Hirsch for advice, and to Dr. E. B. Coolley and others for co-operation.

[3]Among these, the second case of Putti (22) does not appear entirely typical. Unfortunately, its exhaustive histologic studies have caused a widespread discussion and the formation of an etiologic theory.

[4]These reports have been added since the paper was prepared for publication.

and the patient could not be communicated with again.

In the following table Dr. Sante's case is included as the nineteenth, but no claim is made as to the completeness of the list.[5]

Fig. 2. Same case as shown in Figure 1. Anteroposterior view of left elbow. The joint is not involved, although the adjacent bones show a continuous hyperostotic flow.

PATHOLOGY

Knowledge of the pathology is derived solely from X-ray examination, and, in five cases, from biopsy studies. As yet, no cases have come to autopsy.

The lesion consists of a dense cortical hyperostosis, resembling sclerotic bone. Such a lesion is expansive, causing an enlargement of the affected part, and extending in a linear track in the form of a longitudinal band, like a hyperostotic "flow." Several authors

Fig. 3. Extensive hyperostosis is confined to hip and femur, being classified as partial continuous flow. The hip joint is ankylosed and heterotopic masses are seen above the acetabulum. Slow progress observed over 14 years. (Case of Geschickter, Miller, and Kraft.)

observed dense zones of eburnation in the cortex of long bones with encroachment upon the medulla. In the 19 cases described, the changes were confined to a single extremity, either upper or lower.[6] In his first case Léri found an isolated

[5]Almost two years ago, the writer heard of observations in Australia, but he was unable to verify statements in spite of a communication with Dr. Colin McDonald, of Melbourne.

[6]The tendency of the lesions to involve only a single extremity is unique among bone diseases, with the possible exception of Ollier's chondrodysplasia. The idea that this latter condition is a separate entity is, however, seriously contested according to the review of Bromer and John (1).

SUMMARY OF 19 CASES OF MELORHEOSTOSIS*

Number	Authors	Affected extremity	Extent of lesions (See classification in "Pathology")	Sex	Reported in	Age of Patient	Age of Onset	Histologic studies
1	Léri-Joanny	Left upper	Complete continuous flow	Female	1922	39	10	+
2	Lewin-McLeod	Right upper	Partial continuous flow	Male	1925	35	6	
3	Muzii (19)-Putti	Left lower	Complete continuous flow	Female	1926	10	5	
4	Putti	Left lower	Interrupted flow	Female	1927	8	7	+
5	Zimmer	Left lower	Interrupted flow	Male	1927	32	21	+
6	Perussia-Meda (14)	Right upper	Complete continuous flow	Not stated	1927	....	....	
7	Valentin (26)	Right upper	Complete continuous flow	Female	1928	17	15	
8	Meisels (15)	Right lower	Interrupted flow	Female	1928	25	21	
9	Kemkes (7)	Right upper	Complete continuous flow	Male	1929	54	42	
10	Milani (18)	Right lower	Interrupted flow	Male	1930	....	....	
11	Léri-Loiseleur-Lièvre	Right upper	First: circumscribed flow Later: interrupted flow	Male	1930	39	29	+
12	Kahlstorf (5)	Left lower	Interrupted flow	Male	1930	33	30	
13	Junghagen	Right upper	Interrupted flow	Male	1930	....	....	+
14	Piergrossi	Right lower	Interrupted flow	Male	1931	36	14	
15	Rokhlin	Left upper	Interrupted flow	Female	1931	25	14	
16	Weil-Weismann-Netter	Right upper	Interrupted flow	Male	1932	37	22	
17	Kraft	Left upper	Complete continuous flow	Male	1932	40	22	
18	Geschickter-Miller-Kraft	Right lower	Partial continuous flow	Female	1932	37	23	
19	Sante	Right upper	Circumscribed flow	Male	....	....	....	

*Five cases are reported from Italy, four from the United States, three each from France and Germany, and one case each from Poland, Switzerland, Sweden, and Russia. There is a predominance of males (11:7) and of the right side (12:7).

nodule on the lateral chest wall opposite the side of the affected limb. This node, however, was not radiopaque and did not show the typical features of hyperostosis.

The circumscribed appearance in Sante's case has influenced me to classify the cases according to the extent of the lesions. I differentiate between:

1. Complete continuous flow (far-advanced stage).
2. Partial continuous flow (advanced stage).
3. Interrupted flow (advanced stage).
4. Circumscribed flow (early stage).

It is my belief that the four groups merely represent different stages in the progress of the disease. As the lesions continue to spread, a case may easily change from one group to another. The progressive nature is clearly indicated by the characteristic histories and, in the case of Léri, Loiseleur, and Lièvre (cited below), by radiographic proof.

Group 1. In a few cases, the hyperostosis is spread over the entire extremity (Figs. 1 and 2). Dense, ivory-like cortical proliferations extend as a *complete continuous flow* from the shoulder down to the fingers. Such hyperostosis, which is confined to one side of a bone, unless far advanced, seems to follow the course of vessels and nerves without actual relationship. The hyperplastic material shows an irregular wavy contour, with numerous small ridges parallel to the long axis of the bone. Léri compared the masses with the molten stream of a candle.

Group 2. The *partial continuous flow*

is characterized by the same features as the first group, but one-half of the extremity remains intact. Figure 3 illustrates such a condition of the proximal parts of a lower extremity, the lesions having remained fairly stationary for 14 years, without developing into a complete continuous flow. In the case of Lewin and McLeod (Figs. 4 and 5), only the distal parts of an upper extremity are involved, in spite of a pathologic history of 35 years' duration.

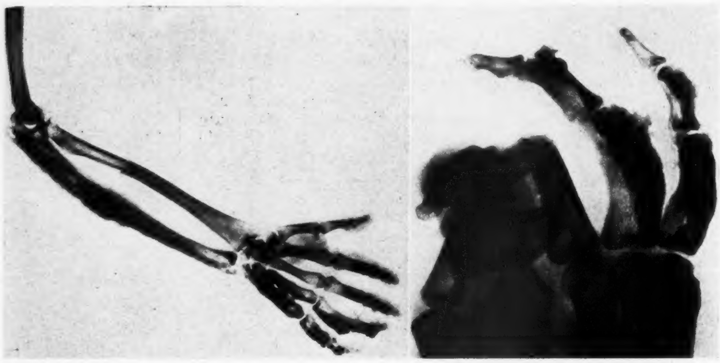

Fig. 4 *(left)*. Partial continuous flow involves the ulna, triquetrum, pisiforme, capitatum, hamatum, metacarpals, and phalanges of fourth and fifth fingers. Ankylosis of carpometacarpal joints. (Case of Lewin and McLeod.)

Fig. 5 *(right)*. Same case as shown in Figure 4. The hyperostosis is sharply confined to one side of the bones. Note irregular borders, spur formations, and bowing deformities. The history dates back 29 years to the age of 6.

Group 3. The *flow*, although spread over an entire extremity, is sometimes *interrupted* in several places (15, 16, 17; Figs. 6 and 7).

Group 4. A *circumscribed flow* was described above in the case of Sante (Fig. 8). The hyperostosis, which was confined to one metacarpal and contiguous phalanx, presented a fairly regular contour. The process remained stationary during an observation of 21 months. A condition similar to this, but further advanced, is illustrated in Figure 9 (12), in which the previously normal humerus has become hyperostotic in the course of years. This is the only case which has changed from a circumscribed to an interrupted flow under actual radiographic control.

Piergrossi (21) differentiates between two successive phases of development. In the first, there is mainly osteosclerosis, slight enlargement, and fairly regular outline of bones. The second phase, as seen in adults, is characterized by considerable irregular enlargement, supposedly due to periosteal proliferation.[7]

The lesions usually spare the joints: only in advanced cases may one find an ankylosis (Figs. 1, 3, and 4). The affected bones are very compact and have no tendency to fracture, in contrast to the somewhat similar marble bone disease.

When the shoulders or hips are affected, bony masses appear frequently in the soft parts, lodging in muscles, and sometimes bulging under the skin. These heterotopic formations are of bizarre appearance and partly confluent (Figs. 1, 3, and 6).

[7]The first phase corresponds to the circumscribed flow, the second, more or less to the interrupted and continuous flow. However, one may see both phases in different parts of the affected extremity. The periosteal changes cited by Piergrossi and others are of doubtful significance.

Fig. 6. The flow is fairly continuous from hip to knee, but is interrupted in leg and foot. Heterotopic hyperostosis is seen in inguinal region, resembling the subclavicular formations in Figure 1. In contrast to findings on Figure 3, the lateral portion of the femur is involved, this being the most frequent type of femoral affection. (Case of Meisels.)

characteristic features from which to make a diagnosis of melorheostosis.

SYMPTOMATOLOGY

The symptoms are characterized by an insidious onset and slow manifestation. Owing to the fact that the findings are sometimes incidental in the course of routine examinations, one may consider a small group as quiescent. Patients with symptoms complain of low-grade, intermittent rheumatic pain which sometimes disappears for months, and even years, although the lesions may be progressive. Usually the complaints are rather vague, even when the joints become involved.

In the advanced cases, bowing deformities[8] of bones occur which may result in shortening of the limb. The muscles tend to become at-

HISTOLOGY

Biopsy material was studied in five cases. The tissues were poor in cells and devoid of osteoblastic activity. An increase in osteoblasts was described by Léri. The osseous lamellæ showed compactness, marked crowding, elongation, and irregular arrangement in various angles. Junghagen (4) always noted a concentric grouping of lamellæ around the haversian canals (Fig. 10). In the heterotopic masses, islands of cartilage were observed by Léri and Roussy (24). The fat marrow in the canals was transformed into fibrous tissue, but the capillaries were found to be normal in most instances. Putti, however, described a vascular abundancy with obliteration of capillaries. On reporting the histologic findings of Zimmer's case, Kauffmann (6) stated that the sections did not present sufficient

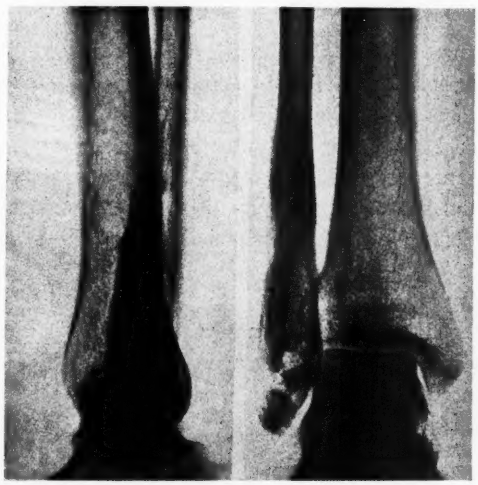

Fig. 7. Same case as shown in Figure 6. The hyperostotic flow is confined to the distal fibula, being interrupted in the tibia and proximal fibula. Tarsals and metatarsals in this case are also involved.

[8]With the exception of Putti's second case, the convexity of the curved bones has always been found on the side of the hyperostosis.

rophic; at times circumscribed erythema and nodular induration occur in the skin of the affected extremity. The first symptoms usually appear during childhood, but they are vague, and many years may elapse before deformities of the fingers (Fig. 11) and limited motion of joints cause the patient to consult a physician. In advanced cases, mechanical interference at important joints may cause some disability, but unless patients suffer intercurrent or incidental diseases, they remain in good health.

Figs. 8-*A (left)* and 8-*B (right)*. Circumscribed flow of fourth metacarpal and contiguous phalanx (marked by arrows). Fig. 8-*A* was taken in January, 1921; Fig. 8-*B*, taken 21 months later, demonstrates a stationary condition. (Case of Sante.)

The physical and laboratory findings are irrelevant.

There is no known treatment for the condition. Spontaneous arrest of progress may occur at any time.

DIFFERENTIAL DIAGNOSIS

The specific findings and clinical features described in the previous sections are helpful in ruling out similar lesions. In order to eliminate the possibility of a syphilitic disorder, serologic tests are essential. Tuberculosis and primary or metastatic neoplasm can be disregarded in view of different physical findings.

In cases with a complete continuous and with an interrupted flow the correct diagnosis is obvious. The partial continuous and the circumscribed flow have to be differentiated from ossifying periostitis, calcinosis, marble bone disease, Paget's disease, sclerosing osteitis, osteopoikilosis, calcified hematoma, especially in hemophilics, and from other affections.

As to whether or not the unilateral involvement as seen in 23 cases is a definite criterion in the differential diagnosis cannot be decided with certainty according to our present knowledge, but it is an outstanding feature of the disease. Whenever a case presents lesions resembling melorheostosis in multiple extremities a very critical consideration of the differential diagnosis is necessary.

ETIOLOGY

Léri advanced the theory that the lesions might be of an infectious nature, but so far

Fig. 9. The lesions are further advanced than those shown in Figure 8. Arrows indicate the seat of hyperostosis. Slow progress, observed over 10 years, resulted in marked involvement of the previously normal humerus. (Case of Léri, Loiseleur, and Lièvre.)

Fig. 10. Biopsy section (case of Junghagen) taken from eburnized olecranon. Narrowness, irregular arrangement, and elongation of osseous lamellæ. No evidence of osteoblasts or vascular changes.

there has been no proof, in spite of elaborate experiments. Putti believes that a lesion of the sympathetic system produces certain vascular changes, with subsequent eburnation of bone along the course of nutrient vessels. Constitutional, endocrine, and hereditary factors are of doubtful importance. There is no reason to believe that the disease has any connection with syphilis, tuberculosis, or malignant neoplasms.

Several authors tried to explain the linear distribution of the hyperostosis by assuming a lesion of a truncal segment during early embryonic life. In discussing Lewin's presentation in 1925, Phemister (20) suggested such a possibility. Lewin and McLeod mentioned the possibility of a lesion of spinal ganglionic origin, with involvement of segments. On the same basis, Zimmer (29) formulated the embryonic theory of a metameric disturbance. His views were discussed in a previous article (8).

Certain cases in which the root of an extremity is extensively involved seem to support Zimmer's theory. However, our present knowledge of the origin and development of limbs is not in accord with these explanations and, in my opinion, it is better to admit that the nature of the disease is still unknown.

TERMINOLOGY

Various names have been applied to characterize the disease: Osteopathia hyperostotica congenita unius membri, osteosis eburnisans monomelica, Léri's disease, and melorheostosis Léri. In a recent article, Weil and Weismann-Netter proposed to change "melorheostosis" to "rheostosis" because, in their case, not only the limb (melos), but also the fourth rib and thoracic vertebra on the same side were hyperostotic, *e.g.*, parts of the skeleton apparently outside of the affected extremity. Their findings,

however, are comparable to those of other cases in which large portions of the scapula, ribs, and pelvic bones, including the fifth lumbar vertebra, are involved and are referable to the root (anlage) of an extremity. Therefore, Léri's term, "melorheostosis" or "hyperostose en coulée sur toute la longeur d'un membre" [monomelic (single limb) flowing hyperostosis], still holds good.

Fig. 11. Same case as shown in Figures 1 and 2. Left thumb and index finger show gross deformities, with multiple bony lumps bulging under the skin. The thumb is held in mid-position due to ankylosis. Similar deformities of fingers induced Weil and Weismann-Netter to make a tentative diagnosis of melorheostosis in their case prior to X-ray examination.

SUMMARY

1. Melorheostosis is a flowing hyperostosis of a single extremity. In preference to other terms, the name "monomelic flowing hyperostosis" is proposed.

2. So far 19 cases have been described in the literature. Four additional cases, not published as yet, have been seen in the United States.

3. In the early cases, the hyperostotic flow is confined to isolated parts of an extremity (circumscribed flow). In the advanced cases, the flow is either interrupted or continuous (interrupted flow, complete, and partial continuous flow). An affection of other parts of the body has never been definitely proved. Microscopically, the tissues do not present specific features.

4. The disease is slowly progressive, but it may become stationary in the early, as well as in the late, stage for many years.

5. The symptoms are rheumatic pain and limited motion of joints. In most cases the complaints are vague, and ankylosis of joints may cause relatively little concern.

6. Only by X-ray examination can diagnosis be made. Occasionally, curving deformities of fingers are sufficiently characteristic to cause one to suspect the disease prior to X-ray studies.

7. The etiology is still unknown, in spite of the fact that the clinical features point toward a congenital nature. The lesions, although resembling other bone diseases, represent a separate entity and are benign in character.

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DISCUSSION

(Continued from Page 13)

side of the forehead and face which had gradually become more noticeable. For six months he had had severe convulsive attacks during which he became unconscious and bit his tongue. Roentgenograms made after his admission to the hospital showed a marked thickening of both frontals and, to some extent, both sphenoids. The right frontal sinus was filled with a dense, bony material. As he had a 4 plus Wassermann, he was regarded as a syphilitic patient. In spite of active anti-syphilitic treatment, the tumor continued to increase in size, the convulsions became more frequent, and the headaches more intense. A decompression was performed and the same treatment administered for two months longer, but with no improvement. The specimen removed at operation was reported as an osteitis fibrosa cystica.

Three months after the beginning of the anti-syphilitic treatment, the roentgenograms showed the process to have increased in extent. The patient was then given roentgentherapy. At the conclusion of this, he was sent home, slightly improved. Three months later his symptoms had almost completely disappeared. The tumor was somewhat smaller. Six months later the tumor had disappeared and the patient felt perfectly well. He has not reported since.

EDITORIAL

THE NATIONAL BOARD OF MEDICAL EXAMINERS RECOGNIZES RADIOLOGY

Radiology has, during the last few years, received deserved recognition by organized medicine. For a long time the American Medical Association was without a radiologic section, radiology being considered in the Miscellaneous Section. Through the enthusiasm and energy of Dr. Albert Soiland, of Los Angeles, the American Medical Association was brought to appreciate the important position radiology held, and a Section on Radiology was organized. This Section has been in successful operation for several years, and its popularity is attested by the large number who contribute to its programs and attend its meetings.

The Southern Medical Association has had an active Section on Radiology for several years, the importance of radiology being thus recognized by this, the second largest medical body in the United States.

It is with a modest degree of pride that RADIOLOGY, the official Journal of the Society, is able to say that it has taken an active part in the latest and one of the most important recognitions to be accorded radiology. The Journal presented in its May, 1932, issue a statistical study on the medical schools of the United States and Canada. We called the attention of the officers of the National Board of Medical Examiners to this presentation of irrefutable evidence of the progress of radiologic education, and their answer is the following communication:

NATIONAL BOARD OF MEDICAL EXAMINERS
Founded, 1915, by William L. Rodman, M.D.
225 South Fifteenth Street, Philadelphia

Waller S. Leathers, M.D. President	Executive Committee (In addition to the officers)
Everett S. Elwood, M.D. Executive Secretary and Treasurer	Walter L. Bierring, M.D. H. S. Cumming, Surg.-Gen., U.S.P.H.S.
J. S. Rodman, M.D. Medical Secretary	Walter E. Garrey, M.D. Merritte W. Ireland, M.D. O. H. Perry Pepper, M.D.

November 1, 1932.

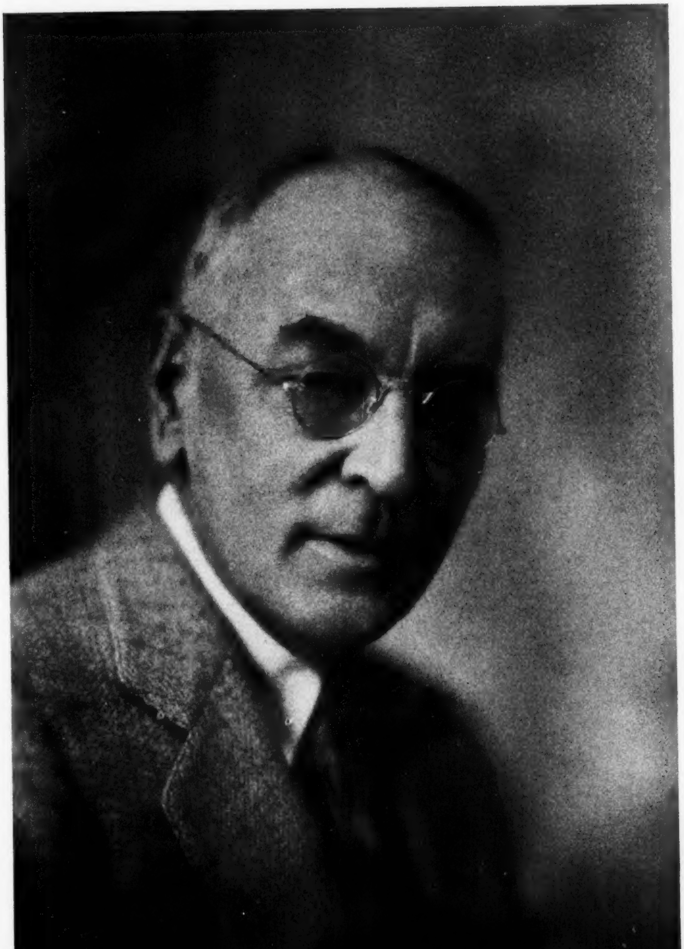
Dear DOCTOR MENVILLE: At a meeting of the Executive Committee of this Board held on October 28, the matter of the recognition of Radiology brought up by you in a letter to Dr. Walter E. Garrey on June 15, was presented.

I am instructed to inform you that the National Board is in sympathy with the recognition of this most important subject and will provide in its next issue of instructions to candidates which explains the contents of the examination in Part III, that questions in Radiology and the recognition of the more usual X-ray plates will be expected.

Sincerely yours,
J. S. RODMAN,
Medical Secretary.

This is the very goal for which radiologists are striving—instruction to be available to medical students, so that they may enter practice with a thorough grounding in radiology, whether or not they purpose to become specialists in it. When internists and surgeons alike shall have received instruction while students as to the indications for roentgenology and the principles which govern radiation therapy, they will be the more ready to confer with other physicians who have specialized in radiology.

This recognition by the National Board of Medical Examiners will be a step in the just appreciation of the limitations of and indications for radiology, and we look for it to result in a clearer understanding of the educational requirements necessary for a physician to become a radiologist. Also, it is to be expected that fewer physicians without intensive training in the use of the X-ray and radium will undertake the employment of these agents, appreciating, rather, that they are not for inexperienced hands.



BYRON H. JACKSON, M.D.
PRESIDENT OF THE RADIOLOGICAL SOCIETY OF NORTH AMERICA

It is a matter of great satisfaction to all of us that so authoritative a body as the National Board of Medical Examiners has thus put itself on record, and is prepared to co-operate with the organized bodies of radiologists that have worked consistently for this educational recognition.

ANNOUNCEMENT

THE MINNESOTA RADIOLOGICAL SOCIETY

The Minnesota Radiological Society held its twelfth meeting at St. Luke's Hospital, Duluth, Minnesota. The following program was presented:

(1) Roentgen Findings in Pneumoconiosis, J. R. McNutt, M.D., Duluth.

(2) Roentgen Therapy in Carcinoma of the Uterine Corpus, F. B. Exner, M.D., Minneapolis.

(3) Roentgen Visualization of the Urethra, Normal and Pathological, M. H. Nicholson, M.D., Duluth.

(4) Atelectasis of the Lungs, F. Hirschboeck, M.D., Duluth.

(5) Roundtable Discussion on Problems of Roentgen Diagnosis and Therapy, conducted by Gage Clement, M.D., Duluth.

Address on Diaphragmatic Hernia: *(A)* Roentgen Aspect, B. R. Kirklin, M.D., Rochester; *(B)* Surgical Aspect, S. Harrington, M.D., Rochester.

IN MEMORIAM

HARRY THEODORE HILLSTROM

Oct. 16, 1902–Oct. 3, 1932

On Oct. 3, 1932, a career of remarkable promise was unfortunately terminated by the death of Dr. Harry Theodore Hillstrom as a result of an accident that he had sustained a short time previously. His loss is a grievous one to all of those who have been associated with him in the Vanderbilt University School of Medicine and in the Vanderbilt University Hospital.

Dr. Hillstrom was born in Carver County, Minnesota, on Oct. 16, 1902. After obtaining an academic degree at the University of Minnesota, he entered the School of Medicine. At the age of 24, when he was in the second year of medical school, it was found that he had diabetes. The discovery of insulin gave him an opportunity to lead a happy, useful life even though he was somewhat handicapped. It is particularly distressing that a person who had the stamina to work and forge ahead despite such a malady should have lost his life so shortly after becoming well established in his chosen field.

He received his medical degree from the University of Minnesota in 1927 and occupied a position there as Teaching Fellow from 1928 to 1930. From 1930 until the time of his death he was an Assistant Professor of Surgery in charge of Radiology in the Vanderbilt Medical School.

Despite the shortness of Dr. Hillstrom's career at Vanderbilt, he made a profound and far-reaching impression. As a teacher, he was inspiring to the clinical staff of the hospital as well as to the students of the medical school. Because of his exceptional training and ability, he was able to devote himself to research and to make a number of important contributions concerning the action of X-rays. Particularly outstanding among these was a recently completed study of the effects of irradiation on the growth of bone, a work which was presented before the American Medical Association in May, 1932.

Dr. Hillstrom's unfailing courtesy and his critical acumen endeared him to his professional colleagues. He won the respect and admiration of all who were privileged to know him intimately. He was a generous and thoughtful companion, a zealous scholar, and a true gentleman. It is with the utmost sorrow that Vanderbilt University has lost one of the most valuable and beloved members of its staff, and RADIOLOGY one of its Assistant Editors.

CASE REPORTS

THE EARLY RECOGNITION OF ANENCEPHALY, WITH A REPORT OF THREE CASES[1]

By W. O. WEISKOTTEN, M.D.
SAN DIEGO, CALIFORNIA

Based on a review of roentgenologic literature covering the past 10 years, it is the opinion of the writer that there must be many unreported cases of atypical pregnancy which have been properly diagnosed, prior to delivery, by means of the roentgen ray. By the same token there must have been many hundreds of abnormal pregnancies which were denied the benefit of prenatal X-ray examination, largely because the attending physician did not recognize the indications or was not familiar with the important possibilities of this modern roentgenologic procedure in these cases. When one considers the great importance of the early diagnosis of obstetric monsters, more important, perhaps, when cesarean section is under consideration, the assumption seems to be justified.

Fig. 1. Case 1. Roentgenogram of eight months' pregnancy, antero-posterior projection.

Since the first published report of Case, in 1917, on the prenatal diagnosis of anencephaly, 18 cases, which were recognized by early roentgenologic examination,

[1]Read before the Radiological Society of North America at the Sixteenth Annual Meeting, at Los Angeles, Dec. 1–5, 1930.

have been reviewed in American medical literature. These have stimulated interest in this diagnostic procedure.

In briefly reporting the three cases of anencephaly which have come to my attention within the past year and a half, it is not my desire to enter into a discussion of the pathology of the fetus or a consideration of the possible factors which might be the cause of this deformity. It is interesting, however, to stress the fact that all three cases had certain features in common which would probably apply to the larger percentage of this particular type of obstetric monster.

The three mothers were referred for X-ray examination by obstetricians who, in each case, had recognized hydramnios and who had obtained a history of convulsive movements of the fetus. In each case the physicians reported inability to locate accurately the fetal head, which was immediately suggestive of the possibility of an atypical pregnancy. In all three cases, after the diagnosis of anencephaly was made, cervical dilatation was immediately accomplished by means of the hydrostatic bag, version was performed, and the fetus promptly delivered, followed by uneventful recovery of the mother.

All of the prenatal roentgenograms showed definite absence of the cranial bones, cephalic presentation and fetal size corresponding to the duration of pregnancy. The fetuses, which were born alive and breathed from one to three hours, were of the male sex and well developed, with the exception of the same cranial malformation. They had the same facial appearance, with bulging eyes and aquiline nose. Roentgenograms showed the typical absence of the cranial bones, but no pronounced spina bifida.

Case 1. A white mother, aged 24 years, primipara. The woman reported no impor-

Fig. 2. Case 1. Roentgenogram of the fetus.

tant previous illness. The first menses, at 14, were painful and profuse. At the time of the present examination, the woman was eight months pregnant, but the abdomen was the size of full term. There was evident excess of amniotic fluid. Rapid increase in the size of the abdomen in the preceding three weeks had been noted.

Case 2. A white mother, age 27 years. There was no history of important illness. There was one normal child, which at birth weighed five pounds, fourteen ounces. There had been prolonged labor and a low

forceps delivery. At the time of examination of the mother, the child was two and one-half years old.

Examination showed normal pelvic measurements and normal blood pressure. The urine and blood Wassermann examinations were negative. At five months of pregnancy, the woman had had severe cramps and a threatened miscarriage. At eight and one-half months, she was referred for X-ray examination.

Fig. 3. Case 2. Typical anencephaly, postero-anterior projection.

Case 3. A white mother, age 32 years. The woman's general health was good, and there was no history of an important illness. The two living children, aged nine and four years, had been normal deliveries, and the health of both was good. One set of twins, born between these two living children, was delivered prematurely at the sixth month. The twins presented cleft palates, and one, spina bifida.

The present pregnancy was of seven and one-half months' duration, but the abdomen corresponded in size to full term. The fetus was floating and the head was not recognized by manual examination.

I wish to thank Dr. L. C. Kinney and Dr. A. E. Elliott for permission to report their case with this series and to comment on the diagnostic quality of the film which permitted so accurate a diagnosis.

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Fig. 4. Case 3. Typical anencephaly, lateral projection.

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A CASE OF INTRATHORACIC CARCINOMA PRIMARY IN THE PLEURA

By ALAN L. HART, M.D., M.Sc. (Med.), Roentgenologist to the Tacoma General Hospital, and DALE L. MARTIN, M.D., M.Sc., Pathologist to the Tacoma General Hospital, TACOMA, WASHINGTON

This case is presented for two reasons: (1) the bizarre roentgenologic picture, and (2) the unexpected result of the postmortem studies.

The patient, a white male, 67 years of age, was first seen in October, 1930. His chief complaints were dyspnea on exertion, which had been present for about nine months, and pain in the right chest. Anorexia had been apparent for three months. A month previous to the examination, the patient had had an attack of pain in the right chest which had lasted a week. This pain had later become constant. It was exacerbated by breathing and by lying on his left side. He had lost 15 pounds in the 3 months preceding examination.

The man gave a history of the usual infectious childhood diseases, malaria for a period of three years in early manhood, and an attack of irregular, rapid heart action in 1922. Careful questioning did not reveal a history of an acute febrile illness that might have been regarded as a pneumonia, pleuritic effusion, influenza, or other serious respiratory infection. Nocturia two or three times nightly had been present for six or seven years, with increased frequency and diffi-

Fig. 1. Film of the chest made at the time of first examination. A roentgenogram made at time of death showed no apparent change. Note the complete obliteration of all lung detail and the diaphragm by the large mass in the right chest.

culty in starting the stream for two or three years previous to this report.

Physical Examination.—Temperature, normal. Pulse, from 75 to 80. Respiration, 20. Blood pressure, 132/94. All teeth had been removed. The head and neck were otherwise negative.

The left chest was emphysematous and hyperresonant throughout. Percussion note over the right chest was dull below the fifth rib in the posterior axillary line and the fourth rib anteriorly. Over this area, breath sounds were absent except along the border of the sternum, and vocal and tactile fremitus were greatly decreased. The right chest showed very little respiratory movement. The left border of the heart was at the anterior axillary line, with the maximum impulse sharply localized just to the left of the midclavicular line. The A^2 was sharply accentuated, but there were no thrills or murmurs. The abdomen was apparently normal. Rectal examination showed a moderately enlarged prostate, smooth, and not unusually firm.

X-ray Examination.—Roentgenograms of the chest (Figs. 1 and 2) showed a dense opacity occupying the lower two-thirds of the right lung field, obliterating all lung detail, and completely obscuring the right diaphragm. The upper third of the right lung and the entire left lung were clear. The ascending aorta and the horizontal arch were distinctly outlined above the shadow, on the lateral view; the descending aorta was entirely obscured. Diagnosis was a probable tumor involving the right lower and middle lobes. The condition was also considered as possibly due to either encapsulated pleural fluid or aneurysm of the descending aorta with atelectasis of the lower and middle lobes.

The patient refused hospitalization, stating that he felt better when ambulant and that he did not consider himself really ill. Although it was advised, thoracentesis was not done.

On Jan. 4, 1931, the man was re-admitted to the hospital with a greatly distended bladder and complete urinary suppression which had lasted for 24 hours. After the acute condition had been relieved, the patient stated that he felt better than when we had examined him 10 weeks before, but that he had lost 30 pounds since July, 1930.

While he was in the hospital, his temperature range was from 98 to 99 degrees, the pulse, from 100 to 75. Wassermann and Kahn tests were negative. The urine showed a trace of albumin, a few pus cells, and a few red blood cells. Blood count: red blood cells, 5,000,000; white blood cells, 8,000; hemoglobin, 13.5 gm. (81 per cent); differential white count, normal.

Roentgen examination of the chest showed no change in the appearance of the right thorax. There was no pulsation in the mass and no movement when the patient

was shaken or changed his position. He left the hospital, improved, on Jan. 7, 1931.

On March 24, 1931, during an automobile ride, the patient said he did not feel well and suddenly collapsed. He was brought to the hospital, but he was found to be dead. Films of the chest were made and an autopsy performed at once.

When the thorax was opened, a large pleural pocket, containing 2,000 c.c. of clear, serous fluid, was found in the right side, occupying the lateral and posterior portion of the right chest. Crossing the cavity were several firm, fibrous, band-like adhesions. The wall of the pocket was thick and yellowish, exuding an apparently purulent material. The left chest was normal except for a few old, fibrous adhesions about the base of the lung. There were apical scars in both lungs and calcified hilum nodes. The heart appeared normal.

The entire lower portion of the right lung was leathery in consistency. Crepitation was absent. The pulmonary surface that bordered the empyema cavity was dark blue in color, and studded with many small, white, elevated nodules less than 1 mm. in diameter. Upon microscopic section, these tiny nodules were found to be carcinoma; the greatly thickened parietal pleura was also carcinomatous.

There were 50 c.c. of free fluid in the abdomen. An old, fibrous band extended from the gall bladder to the hepatic flexure of the colon. There were several pedunculated polypi in the colon, averaging 1.5 cm. in diameter. The prostate was enlarged, Grade II, but was soft and smooth. There were no other gross findings of note.

The histologic characteristics of the sections were clearly those of carcinoma rather than endothelioma. Microscopic section of the lung, including the pleura lining the intrathoracic mass, showed the surface to be covered by several layers of loosely and irregularly arranged cells, apparently epithelial. The infiltration generally was rather uniform with only an occasional alveolar area. The cells were irregular in size, larger than the ordinary endothelial cell, and showed a well stained cytoplasm. The nuclei were moderately hyperchromatic and mitoses were present. Though the epithelial coat was very shallow, it was more than a simple inflammatory hyperplasia. Beneath the pleural surface, the lung showed atelectasis, but no neoplastic change. The remainder of the pulmonary parenchyma was free from carcinoma.

Fig. 2. Lateral film of the chest. The ascending aorta and horizontal arch are distinctly outlined above the mass.

Sections of the parietal wall of the pleural pocket showed a picture similar to that of the lung, except that the process was deeper, being seen among the muscle bundles of the thoracic wall. The cells were in broad masses, usually parallel to the surface, with an occasional alveolar group. In the latter areas, the cells lining the alveoli were rarely one layer deep.

Microscopically, one of the pedunculated polyps of the colon showed the typical picture of a Grade I adenocarcinoma of the bowel.

Microscopic Study.—The heart, spleen, and pancreas showed no marked departure from normal. Microscopic examination of the adrenals showed a general atrophy in the thickness of the cortex and medulla, but the individual cells in both areas presented a normal appearance. The medulla seemed to have suffered the greater loss.

Sections of the kidneys showed marked vascular enlargement and some isolated areas of increased fibrous tissue, mildly infiltrated with lymphocytes, extending through the cortex. In and about an occasional glomerulus, there was also rather heavy lymphocytic infiltration, otherwise the glomeruli appeared normal. The tubules were somewhat dilated; the lining epithelium was flatter than usual; the cells contained colloid material, and the nuclei were absent from some. Some hyaline and fat droplets were found within the lumen of the tubules.

The sinuses of the liver, which were filled with blood, showed some dilatation. The cells, which were somewhat atrophic and slightly granular, presented a loss of cellular outline.

Following the microscopic discovery of carcinoma in the thoracic lesion, believed at autopsy to be an ancient, encapsulated empyema, sections were made from all portions of the hypertrophied prostate. It was felt that this gland might harbor a primary malignancy in spite of its benign gross appearance and negative routine sections. The findings were those described for prostatic enlargement of the simple type with glandular hyperplasia. In no portion was a malignant change suggested.

Because it was not enlarged or nodular and it had been clinically symptomless, the thyroid was not sectioned. Unless it harbored a malignant growth, it seems that, in this case, we are dealing with a primary pleural malignancy of a peculiarly atypical and circumscribed character. Though endotheliomatous, the cellular picture is that of carcinoma.

DISCUSSION

It may be objected that, at autopsy, a small, primary tumor outside the thorax might have been overlooked. The thyroid was not removed because it was neither enlarged nor nodular, but all the other viscera were carefully examined for neoplasms. The stomach and small intestine, which were thoroughly inspected, showed no tumors, ulcers, or superficial erosions. The polyps in the colon were not ulcerated and did not exhibit signs of degeneration. There were no nodules or masses in the prostate, kidneys, adrenals, pancreas, spleen, or liver. The bladder wall was normal. The thymus had been almost entirely replaced by fat. Thus, with the possible exception of the thyroid, all probable sources of primary carcinoma outside the chest have been eliminated.

It is worthy of note that this man's symptoms were insignificant during the greater part of his illness. He was not confined to bed at any time because of his chest condition, and cough and expectoration were practically absent in spite of the fact that the disease was well advanced when he was first examined, six months before his death.

SUMMARY

A case of carcinoma is presented, probably primary in the pleura, which exhibited the roentgenologic and gross pathologic appearance of encapsulated empyema. It was recognized as malignant only by microscopic study of the lung and pleura.

ABSTRACTS OF CURRENT LITERATURE

CONTENTS BY SUBJECT

THE FOLLOWING ABSTRACTORS HAVE CONTRIBUTED TO THIS ISSUE

J. N. Ané, M.D.
Howard P. Doub, M.D.
Hans W. Hefke, M.D.
Paul C. Hodges, M.D.
E. T. Leddy, M.D.
Charles G. Sutherland, M.D.

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BONE (DIAGNOSIS)

The Calcaneal Spur. G. M. Sack. Röntgenpraxis, Feb. 15, 1932, IV, 158-167.

Spurs are exostotic bone growths on the plantar side (tubera calcanei) of the os calcis. Variations in the shape of the calcaneum and rims for the insertion of tendons should not be called "spurs." One may distinguish senile spurs—the formation of which usually begins between the ages of 40 and 50 years—which are caused by osteo-arthritic changes. This type is multiple, usually bilateral, and causes no symptoms.

Another type is a spur formation by inflammatory processes, occurring at any age and often unilateral. The primary cause is a bursitis and peribursitis calcanei through which a periosteal bone growth and spur formation take place. That certain diseases, as gonorrhea, are especially predisposing could not be shown. Neither are deformities of the foot, such as flatfoot, a cause of spurs as often as has been thought. Trauma does not seem to induce them. All the symptoms are caused by inflammatory changes, either primary or secondary to the spur.

The therapy should be conservative, consisting of rest, roentgentherapy, combating the inflammation, and correction of foot deformities. Relief from symptoms is usually obtained in flatfoot by correction of foot deformities. In only a few cases is surgical removal indicated and advisable.

H. W. HEFKE, M.D.

A Rare Finding in Traumatic Lesions of the Elbow. Tullio Bertani. Riv. di Radiol. e Fisica Med., March, 1932, IV, 347-350.

A man, 22 years of age, fell and injured his left elbow. A diagnosis was made of fracture of the

internal condyle of the humerus. Because of the position of the fragments, open suture was undertaken, and at the operation it was found that the lesion was really a fracture of a deposit of bone, which was most likely an inclusion of the epitrochlear nucleus in one of the tendon sheaths.

E. T. Leddy, M.D.

BONE (THERAPY)

Fractures of the Lower Radial Epiphysis. William L. Watson. Arch. Surg., March, 1932, XXIV, 492-504.

The author believes that even after adequate reduction of an epiphyseal fracture, a premature ossification with a resulting wrist deformity may ensue. A careful follow-up should be done on these patients over a period of at least two years. He advises that a conjugal chondrectomy be done as soon as a diagnosis of premature ossification can be made. This consists of excision of the conjugal cartilage of the ulna in order to produce cessation of its growth and thus avoid deformity of the wrist. The amount of longitudinal growth to be expected from the upper epiphysis of the radius is small, so the ulna should be excised at the level of the articulating surface of the radius. This excision of the ulna is a simple procedure and gives a well functioning wrist. If done early enough, it would probably prevent muscle weakness and atrophy.

Howard P. Doub, M.D.

The Rôle of Periosteum in the Healing of Fractures: An Experimental Study. Keene O. Haldeman. Arch. Surg., March, 1932, XXIV, 440-450.

A number of theories have been evolved regarding the rôle played by the various components of bone in the healing of fractures. The author has summarized these theories from the works of Bancroft. They are as follows: (1) Periosteal theory—this presupposes that the periosteum and endosteum are definite organs for bone formation in repair, and that the bone cells arise from them and from no other source; (2) osteoblastic theory—this assumes that there are definite bone cells which take up the function of repair; (3) the theory of the extracellular deposition of calcium salts assumes that there is chemical repair without any definite bone-producing cells.

The author conducted a series of experiments on animals under the following groups: *(A)* Saw cut in each radius, stripping the periosteum on the left; *(B)* segment removed from each radius, stripping the periosteum on the left; *(C)* segment removed from each radius, drawing the periosteum over the ends of the right radius; *(D)* segment removed from each fibula of a dog, drawing the periosteum over the ends of the right fibula.

From the above experimental procedures, the author draws the following conclusions: (1) Periosteum plays the chief rôle in the healing of fractures; (2) endosteal callus aids in the healing of fractures, but in the absence of periosteum is often unable to complete the union; (3) the interposition of periosteum between the ends of the fractured bone may result in non-union.

Howard P. Doub, M.D.

Fractures of the Upper End of the Humerus: An End-result Study which Shows the Advantage of Early Active Motion. Sumner M. Roberts. Jour. Am. Med. Assn., Jan. 30, 1932, XCVIII, 367-372.

These fractures are defined as those at or above the level of the surgical neck of the humerus. The data used were gathered from the records of the fracture service at the Massachusetts General Hospital. The patients were treated by three different services: two surgical and one orthopedic, and by a considerable number of different surgeons, all agreeing on the main principles of procedure. The results are grouped under the headings of anatomic, economic, and functional.

Classification on anatomic lines is sometimes inconvenient and difficult. A division into two groups, transverse fractures of the surgical neck and comminuted fractures, obviates uncertainty of exact location and accords with different lines of treatment. Compared with ten years ago, there has been a marked trend away from prolonged fixation and the position of abduction toward simple fixation and early active motion. The end-results of such treatment are good.

C. G. Sutherland, M.D.

BONE DISEASES (DIAGNOSIS)

Aseptic Necrosis of the Neck of the Femur in Adolescents: Osteochondritis Juvenilis of the Neck of the Femur. G. Gütig and A. Herzog. Röntgenpraxis, June, 1932, IV, 504-513.

The aseptic necrosis of the neck of the femur in adolescents may be compared with Calvé-Legg-Perthes' disease of the head of the femur. Many cases of coxa vara in young persons may be explained by it. Aseptic areas of necrosis are found in the neck of the femur or the major trochanter. Clinical symptoms are limping or other disturbances in the gait. Pain is not present or localized. Several such cases are described in detail and roentgenograms of them shown. The pathologic anatomy, genesis, therapy, final outcome, and therapy are discussed. The difference of this disease from Legg-

Perthes' disease is the localization. Tuberculosis, separation of the epiphysis, and fracture of the neck must be considered occasionally in differential diagnosis.

H. W. Hefke, M.D.

Generalized Osteitis Fibrosa Cystica Associated with a Parathyroid Adenoma. T. P. Noble. Jour. Bone and Joint Surg., January, 1932, XIV, 181-185.

The author reports from Bangkok, Siam, what he believes to be the eighteenth recorded case of generalized osteitis fibrosa cystica in which there was a demonstrable parathyroid adenoma. The tumor was not demonstrated at operation but was found at autopsy.

Paul C. Hodges, M.D.

So-called Fibrosarcoma of Bone: Bone Involvement by Sarcoma of the Neighboring Soft Parts. Charles F. Geschickter. Arch. Surg., February, 1932, XXIV, 231-291.

The author states that while this group of tumors usually has a structure indicating a connective tissue origin, the current conception that these fibrosarcomas which invade the bone are all products of the non-osteogenic layers of the periosteum is erroneous. They vary considerably as to origin, and may arise either from this investing portion of the periosteum or from a similar connective tissue or fascia, investing muscles, vessels, or nerve trunks in the overlying soft parts.

He classifies these tumors under the following headings: (1) Tumors of the fibrospindle cell group; (2) neurogenic tumors, involving the bone; (3) osseous invasion by miscellaneous tumors of connective tissue origin—*(a)* angioma of bone, *(b)* myosarcoma and lipoma.

Fibrospindle Cell Group.—This is a disease of adult life occurring most frequently beyond the age of thirty. The lower extremity is usually the site of predilection, the region of the femur being most often involved. The swelling is smooth in contour and differs from the ordinary type of soft sarcoma in the depth of its location and its firm attachment to the underlying bone. The interference with function is also more rapid in the affected limb because of its proximity to the bone. An unusual feature of this disease is that the growth, when occurring near the end of the bone, may extend across the joint and involve the neighboring bone. Metastases to lymph glands have not been found. It is somewhat similar to other forms of sarcoma of bone in its general characteristics and location, but tends to destroy the bone from without inwardly. The one constant feature in the roentgenogram is this extra-osseous soft shadow which is more opaque than the cartilaginous masses seen in periosteal chondrosarcoma, and less dense than the true bone formations seen in osteogenic sarcoma. Considerable bone destruction is frequently seen, but only occasionally is a calcareous deposit seen in a tumor. The size of the soft-part tumor which exceeds the area of bone destruction is a helpful diagnostic point. This is usually large before much evidence of bone destruction is found.

At operation the tumor is usually encapsulated, is firm and fibrous in consistency, and often has a definite peculiarity of being arranged in whorls and strands which run in a number of diverging directions.

The tumor springs from a small spindle- or oat-shaped cell which transforms into a more elongated, spindle-shape and then into a prolonged fibroblast, with an ever increasing amount of intercellular material of the eosin-staining collaginous type. The author goes into the microscopic anatomy in considerable detail.

In 22 cases, none of the patients died within a period of five years after treatment; and in all cases of primary amputation in which adequate follow-ups were available, the patients were cured and were living from six to twelve years after operation.

The tumor is not particularly radiosensitive, and after a local operation followed by roentgentherapy and radium, it has usually recurred. Radiation therapy, however, is recommended in cases in which a complete resection is not possible.

Neurogenic Tumors Involving Bone.—He describes a series of cases which could be specifically related to the nerves in the vicinity of bone. Clinically and in the roentgenogram, these neurogenic tumors bear close resemblance to the lesions of the fibrospindle cell series just discussed. Like the fibrosarcomas, the neural tumors may have a marked fibrillar structure and show under the microscope many spindle cells. Very frequently the differential diagnosis between the fibrospindle cell type and the neurogenic type is not made.

The bone involvement, as shown in the roentgenogram, is more pronounced in the neurogenic sarcoma than in the fibrospindle cell sarcoma. There is frequently considerable osteolytic bone destruction. The tumors are less firm and more fleshy than the fibrospindle cell sarcoma.

The prognosis for life, in cases of neurogenic sarcoma, even after primary amputation, is not good. These tumors recur promptly after local operation, and are not radiosensitive. There is only one cure in this series, extending over five years. This bad prognosis is in marked contrast to the results obtained in the group of fibrosarcomas described in the previous division.

Angioma of Bone.—Three benign hemangiomas of bone are described. They simulate, in the roentgenogram, a peculiar soap-bubble effect extending into the periosteal zone and producing only slight erosion of the bone. At operation, a thin bone shell was

found, and the tumor beneath had the appearance of an altered blood clot. These occurred in adults over 20 years of age, with a history of trauma in each case. Under the microscope, the three cases showed histologic variation characteristic of the benign hemangiomas that are found in the soft parts and subcutaneous tissues. All were operated on by local excision with complete cure and no metastases.

Myosarcoma and Lipoma.—The author reports one case of myosarcoma of the lower end of the left femur. The patient had local excision several times, and died three years and four months after amputation, with pulmonary metastases.

The other patient was a girl, 15 years of age, with a swelling of one month's duration in the region of the knee joint. Roentgenograms showed a soft part swelling slightly eroding and roughening the internal condyle of the femur. A section showed a typical, benign lipoma. This was excised by local operation.

HOWARD P. DOUB, M.D.

Spontaneous Fracture (Carcinomatous Metastasis) of the Dens Epistrophei without Compression of the Spinal Cord. H. Hamperl and A. Maller. Wien. klin. Wchnschr., Jan. 1, 1932, XLV, 24-27.

In a 74-year-old patient there occurred a spontaneous fracture of the dens epistrophei, caused by a metastasis from a prostatic carcinoma. There was a marked dislocation of the skull from the cervical spine. Neither clinically nor during autopsy could any lesion of the central nervous system be demonstrated. Cases of this type are exceedingly rare and seldom described.

H. W. HEFKE, M.D.

BONE DISEASES (THERAPY)

Roentgentherapy of Osseous Metastasis from Carcinoma of the Breast. Lorenzo Feci. Archivio di Radiologia, January-February, 1932, VIII, 5-14.

The author reports a case of osteoclastic metastasis to the frontal bone from an adenocarcinoma of the breast which had been operated on three years previously. The patient had had one course of both pre- and post-operative roentgentherapy. X-ray treatment at high voltage through an anterior and lateral field produced a disappearance of symptoms, which has lasted for two years. The author emphasizes the great radiosensitivity of osseous metastasis and advances as a theoretical explanation for it that the irradiation might have decreased the virulence of the cells in the metastasis.

E. T. LEDDY, M.D.

Quick Healing of Bone Atrophy after Roentgen Irradiation. H. Eckstein. Med. Klinik, Sept. 11, 1931, XXVII, 1353.

Some years ago the author reported the disappearance of pain in his hip after a diagnostic exposure. He observed the quick beneficial effect of small doses of X-rays in a woman with marked bone atrophy of the left leg and femur after a thrombosis in the left leg. One-fourth of an erythema dose of soft rays was given, with immediate good results, while previously the progress had been very slow. Five weeks after the irradiation the bones showed a normal appearance.

H. W. HEFKE, M.D.

CANCER (DIAGNOSIS)

Case Report; Primary Carcinoma of the Lung, with Metastases. Tobias B. Weinberg and Henry Friedland. Jour. Am. Institute Homeopathy, April, 1932, XXV, 415-420.

The authors report the case of a man, 55 years of age, who complained of persistent cough, with profuse expectoration, dyspnea, fatigability, loss of weight, swelling of the ankles, and precordial pain, Six years prior to admission, because of dyspnea and precordial pain, he consulted a physician, who made a diagnosis of asthma and chronic bronchitis. About two weeks before admission the patient had a moderate hemoptysis.

Physical examination was essentially negative, except for moist râles which were heard posteriorly over both lungs at the angles of the scapulæ. Radiographic examination showed a dense circular shadow adjacent to the mediastinum on the left side at the level of the auricle, which was suggestive of a neoplasm apparently originating from the mediastinum. Two months later, X-ray examination revealed evidence of metastatic carcinoma in the left parietal region of the skull. A roentgenogram made of the chest about three months after admission showed the presence of a large amount of fluid in the left chest which obscured the shadows of the mass.

Bronchoscopic examination at about this time showed the inferior wall of the left main bronchus to be displaced upward, which gave the impression of an extra-bronchial neoplasm. Clinically, the patient's symptoms became progressively worse and death followed. Postmortem examination showed the presence of a large mass in the external region of the lower lobe of the left lung, with metastatic lesions in the adrenals, kidney, pancreas, mesenteric lymph nodes, and skull.

J. N. ANÉ, M.D.